SOEHREN

Technical/Agency Draft
December 8, 1994

RECOVERY PLAN

FOR

THE SACRAMENTO-SAN JOAQUIN DELTA NATIVE FISHES

U. S. Fish and Wildlife Service
Region 1, Portland OR

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U. S. Fish and Wildlife Service
Region 1, Portland OR

THIS IS THE DRAFT DELTA NATIVE FISHES RECOVERY PLAN. IT IS BEING REVIEWED BY THE U.S. FISH AND WILDLIFE SERVICE. IT DOES NOT NECESSARILY REPRESENT OFFICIAL POSITIONS OR APPROVALS OF COOPERATING AGENCIES (AND IT DOES NOT NECESSARILY REPRESENT THE VIEWS OF ALL INDIVIDUALS) WHO PLAYED KEY ROLES IN PREPARING THIS PLAN. THIS PLAN IS SUBJECT TO MODIFICATION AS DICTATED BY NEW FINDINGS AND CHANGES IN SPECIES STATUS, AND COMPLETION OF TASKS DESCRIBED IN THE PLAN. GOALS AND OBJECTIVES WILL BE ATTAINED AND FUNDS EXPENDED CONTINGENT UPON APPROPRIATIONS, PRIORITIES, AND OTHER BUDGETARY CONSTRAINTS.

LITERATURE CITATION SHOULD READ AS FOLLOWS:

U.S. Fish and Wildlife Service. 1994. Technical/Agency Draft Sacramento-San Joaquin Delta Native Fishes Recovery Plan. U.S. Fish and Wildlife Service, Portland, Oregon.

EXECUTIVE SUMMARY

FOR THE SACRAMENTO-SAN JOAQUIN DELTA NATIVE FISHES RECOVERY PLAN

Current Status: Seven fish species are included in the Sacramento-San Joaquin Delta Native Fishes Recovery Plan. The delta smelt is listed as a threatened species. The Sacramento splittail (splittail) was proposed as a threatened species on January 6, 1994. To provide greater clarity and since a final rule is anticipated in the near future for this fish, this recovery plan will recommend recovery criteria for the splittail that will be appropriate should the species be listed. Longfin smelt and green sturgeon are Category 2 species. Spring-run, late fall-run, and San Joaquin fall-run chinook salmon are potential candidates for threatened or endangered status in the future. Information is also included on Sacramento perch, a species believed to be extirpated from the Delta at this time.

Habitat Requirements and Limiting Factors: The seven species included in this recovery plan depend on the Sacramento-San Joaquin Delta for a significant segment of their life history. Threats to the Delta ecosystem and these species include loss of habitat due to increased freshwater exports which have increased salinity, loss of shallow-water habitat due to dredging, diking and filling, introduced aquatic species that have disrupted the food chain, and entrainment in State, Federal and private water diversion. State and Federal water projects have also changed the pattern and timing of flows through the Delta. The salmon races are affected by sport and commercial harvest as well as hybridization with hatchery stocks.

Recovery Objective: Delisting of delta smelt and splittail. Restoration of longfin smelt, green sturgeon, spring-run, late fall-run, and San Joaquin fall-run chinook salmon.

Recovery Criteria: Recovery criteria are quantifiable and species specific and can be used to 1) monitor effectiveness of recovery actions, 2) determine when a species has recovered to a secure level (stabilized), and 3) determine when a species qualifies for delisting (if formally delisted). In many cases, recovery criteria are based on two independent measures: population abundance and geographic distribution. For each species a historic base period was established using available data to characterize abundance and distribution during a pre-decline period. The time period over which abundance and distribution criteria must be met was set at five generations. For five of the seven species there is an additional requirement of meeting the criteria through a minimum number of years of stressful environmental conditions.

Action needed:
1. Enhance and restore aquatic and wetland habitat in the Sacramento-San Joaquin River estuary.
2. Reduce effects of commercial and recreational harvest.
3. Reduce effects of introduced aquatic species on Delta native fishes.
4. Change and improve enforcement of regulatory mechanisms.
5. Conduct monitoring and research on fish biology and management requirements.
6. Assess recovery management actions and re-assess prioritization of actions.
7. Increase public awareness of importance of Delta native fishes.

Total Estimated Costs of Recovery:

Costs: (000,000's)

Year	Need 1	Need 2	Need 3	Need 4	Need 5	Need 6	Need 7	Total
1995	20.1	1.5	0.6	1.3	1.5	0	0.2	25.2
1996	21.1	1.4	0.5	1.3	1.5	0	0.1	25.9
1997	21.1	1.3	0.4	1.2	1.5	0	0.1	25.6
1998	20.1	1.3	0.4	1.2	1.4	0	0.1	24.5
1999	20.1	1.3	0.4	1.2	1.4	0.1	0.1	24.6
Total Costs	102.5	6.8	2.3	6.2	7.3	0.1	0.6	125.8

Date of Recovery: Delisting should be initiated in 1999, if recovery and delisting criteria have been met.

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1. INTRODUCTION

This recovery plan is intended to fulfill one of the primary purposes under section 2 of the Endangered Species Act of 1973--to provide a means for the conservation of ecosystems upon which endangered and threatened species depend. According, the purpose and scope of this recovery plan is to outline a strategy for the conservation and restoration of the Sacramento-San Joaquin Delta that currently supports or has the potential to support Delta native fishes. Addressing the Delta ecosystem as whole is a difficult proposition, considering its biotic and physical complexity and the fact it has been, and continues to be, highly altered by human activities (Moyle and Herbold 1989). At least 55 species of fish have been recorded from the Delta, 25 of them native (Table 1). Many of these species, both native and introduced, are in decline (Herbold *et al.* 1992). The most practical way to develop recovery recommendations that would take into account the complexity of the Delta ecosystem was to work with a selected group of fishes. Species addressed in this plan include: delta smelt, longfin smelt, Sacramento splittail (splittail), green sturgeon, spring-run chinook salmon, late fall-run chinook salmon, San Joaquin fall-run chinook salmon, and Sacramento perch. The species selected had the following characteristics:

1. They were known to be in decline and were potential candidates for threatened or endangered status in the future. This characteristic excluded Sacramento fall-run chinook, steelhead, and white sturgeon, which while in decline, were abundant enough to support commercial fisheries. It also excluded tule perch and prickly sculpin, native species that have probably declined in abundance but are still common.

2. Records on the importance of the species to the Delta ecosystem had to be available. This characteristic allowed the inclusion of Sacramento perch, although it is thought to be extirpated from the Delta at this time. Sacramento perch are addressed as a candidate species to reintroduce into its native habitat. Coho salmon were excluded by this characteristic because records of their importance to the Delta ecosystem were sketchy.

3. They were species that depended on the estuary for a significant segment of their life history. This characteristic excluded native resident species whose habitats were mainly upstream of the Delta, such as hardhead and squawfish.

4. The environmental requirements of the combined species covered a wide range of seasons and habitats, so it was reasonable to expect that a joint recovery plan would improve conditions in the Delta for fish in general.

5. They were species for which information was available to make reasonable judgements as to measures that could reverse downward trends in their populations. This characteristic excluded river lamprey, a species about which there is concern over its status in the estuary but for which virtually no information exists. Winter-run chinook salmon are being addressed by the Winter Run Recovery Plan, which will be released soon. The two recovery teams coordinated efforts to ensure a consistent approach to restoring the Delta ecosystem.

The basic objective of the Delta Native Fishes Recovery Plan is to establish self-sustaining populations of the species of concern that will persist indefinitely. For chinook salmon, green sturgeon, and splittail, the recovery goals include having large enough populations so that a limited harvest can once again be sustained. The basic strategy for recovery is to manage the estuary in such a way that it is better habitat for aquatic life in general and for the fish species of concern in particular. Restoration of the Delta ecosystem should also include efforts to reestablish the extirpated Sacramento perch.

Table 1.1. Fishes of the Sacramento-San Joaquin Delta. An asterisk (*) indicates a native species. A = anadromous; R = resident; N = nonresident visitor; M = euryhaline marine. Under status "Sp. Conc." indicates the species is listed as a Species of Special Concern by the California Department of Fish and Game.

Common Name	Scientific name	Life Hist	Status
Pacific lamprey*	Lampetra tridentata	A	declining
River lamprey*	Lampetra ayersi	A	rare
White sturgeon*	Acipenser transmontanus	A	declining; fishery
Green sturgeon*	A. medirostris	A	Category 2
American shad	Alosa sapidissima	A	declining; fishery
Threadfin shad	Dorosoma petenense	A	declining; common
Steelhead*	Oncorhynchus mykiss	A	declining; fishery
Pink salmon*	O. gorbuscha	A	Rare
Chum salmon*	O. keta	A	Rare
Coho salmon*	O. kisutch	A	Rare
Chinook salmon*	O. tshawytscha	A	declining:
Sacto. fall run			fishery
S.J. fall run			low pop.
late fall run			Sp. Conc.
winter run			Endangered
Sac. spring run			Sp. Conc.
S. J. spring run			Extinct
Longfin smelt*	Spirinchus thaleichthys	A-R	Category 2
Delta smelt*	Hypomesus transpacificus	R	Threatened
Wakasagi	H. nipponensis	R?	Invading
Thicktail chub*	Gila crassicauda	R	Extinct
Hitch*	Lavinia exilicauda	R	Unknown
Sacto. blackfish*	Orthodon microlepidotus	R	Unknown
Sacto. splittail*	Pogonichthys macrolepidotus	R	Threatened (proposed)

Hardhead*	Mylopharodon conocephalus	N	Sp. Conc.
Sacto. squawfish*	Ptychocheilus grandis	R	Common
Fathead minnow	Pimephales promelas	N	Rare
Golden shiner	Notemigonus chrysoleucas	R?	Uncommon
Common carp	Cyprinus carpio	R	Common
Goldfish	Carassius auratus	R	Uncommon
Sacto. sucker*	Catostomus occidentalis	R	Common
Black bullhead	Ameiurus melas	R	Common
Brown bullhead	A. nebulosus	R	Uncommon
Yellow bullhead	A. natalis	R	Rare?
White catfish	A. catus	R	Declining; abundant
Channel catfish	Ictalurus punctatus	R	Common
Blue catfish	I. furcatus	R?	Rare
West. mosquitofish	Gambusia affinis	R	Abundant
Rainwater killifish	Lucania parva	R?	Rare
Striped bass	Morone saxatilis	R-A	Declining; abundant
Inland silverside	Menidia beryllina	R	Abundant
Sacto. perch*	Archoplites interruptus	N	Rare
Bluegill	Lepomis macrochirus	R	Common
Redear sunfish	L. microlophus	R	Uncommon
Green sunfish	L. cyanellus	R	Uncommon
Warmouth	L. gulosus	R	Uncommon
White crappie	Pomoxis annularis	R	Common
Black crappie	P. nigromaculatus	R	Uncommon
Largemouth bass	Micropterus salmoides	R	Common
Smallmouth bass	M. dolomieui	R	Uncommon
Bigscale logperch	Percina macrolepida	R	Common
Yellow perch	Perca flavescens	N	Rare

Tule perch*	Hysterocarpus traski	R	Declining; common
Threespine stickleback*	Gasterosteus aculeatus	R	Common
Yellowfin goby	Acanthogobius flavimanus	R	Declining; common
Chameleon goby	Tridentiger trigonocephalus	R	Invading
Staghorn sculpin*	Leptocottus armatus	M	Common
Prickly sculpin*	Cottus asper	R	Abundant
Starry flounder*	Platichthys stellatus	M	Declining; common

PHYSICAL ENVIRONMENT

The Sacramento-San Joaquin estuary (Figure 1.1) has been well described in a number of publications (e.g., Herbold *et al.* 1992). The Delta is the uppermost part of the system, where the two rivers meet, and is largely a tidal freshwater system. The seven fishes of primary concern depend on the entire estuary, but the Delta is the most highly altered part of the system where most problems for fish exist. Hence, management efforts for recovery of the fishes will necessarily focus largely on reducing problems in the Delta and secondarily in Suisun Bay, immediately downstream from the Delta. This section of the Plan describes major aspects of the physical environment of the upper estuary that are important to the native, estuarine-dependent fish species.

Flow patterns in Delta channels are the principal element used to describe habitat conditions because most channels have been dredged and shallow areas have been separated from the river by an extensive series of levees. Thus, little connection to shallow wetland habitats and little diversity in salinity or depth remain. The flow patterns are determined largely by the interactions of freshwater inflow, tidal action, and water diversion.

Fresh water flows into the Delta principally through two rivers; the Sacramento River usually carries about 80% of Delta inflow while the San Joaquin River carries most of the rest. Other streams (including the Mokolumne and Cosumnes rivers) rarely carry more than 5%. On a daily basis, users within the Delta historically have taken up to 57% of the inflow each year while users exporting water from the Delta have taken between 1 and 96% of the inflow each year. Consequently the percentage of Delta inflow that makes it to Suisun Bay ranges from less than zero to nearly 100%. Delta inflows, local usage, and export rates vary strongly depending on season and the quantity and pattern of precipitation within the watershed. The historic record of the daily estimates of Delta inflows, net flows in particular channels, local uses, and export rates are contained in the DAYFLOW database maintained by the California Department of Water Resources (DWR). Variables from DAYFLOW discussed in this recovery plan include:

QTOT =	Total Delta inflow
QOUT =	Net delta outflow to the bay
QSAC =	Sacramento River flow into the Delta
QSJR =	San Joaquin River flow into the Delta
QEXP =	Total exports from the Delta
QWEST =	net movement of water on the lower San Joaquin, effectively the amount of water entering the central Delta minus the amount of water exported.

In the western Delta and Suisun Bay, a large discrepancy exists between the net flows as reported in DAYFLOW and the actual flows in river channels. Daily tidal excursions, spring-neap tidal cycles and irregular meteorological conditions can often overwhelm the physical movements due to river flow. Nevertheless, net Delta outflow is strongly tied to a wide array of important physical parameters that affect most aquatic species of the estuary. Net Delta outflow is closely tied to most of the flow rates reported in DAYFLOW. Thus, increases in net Delta outflow are accompanied by reductions in residence times in Delta channels, increases in quantity of the wetted perimeter, increases in the abundance of flooded vegetation (which a number of species use for spawning and rearing), and decreases in temperature, salinity, percentage of water exported, and local water consumption rates.

An important parameter related to net Delta outflow is the structure and position of the mixing zone. Where sea water and fresh water meet, the difference in density can cause stratification of the water column. In channels where the mixing zone occurs, the difference in density causes the surface movement of fresh water towards the ocean to be countered by a landward flow of salt water along the bottom. At some landward point this stratification of salinity and flow breaks down and the bottom waters mix with the surface waters. Particulate material settles out of the surface fresh water down to the landward flowing bottom currents. These particles, including particulate organic carbon, phytoplankton, zooplankton, and larval fish become concentrated within this entrapment zone.

Shallow depths prevent stratification and entrapment from occurring. However, in shallow areas, phytoplankton productivity tends to be much higher because algae are constantly within range of sunlight. Experiments have shown that the shallow areas of Suisun Bay are ten times as productive as the channels. Tidal currents transport material from the shallows to the channels where entrapment processes can concentrate particles. Thus, algal growth is fastest in shallows but the highest concentrations of biomass are usually found in the channels.

The mixing zone and entrapment zone are usually found in areas where surface salinities are between 2 and 10 parts per thousand (ppt). In channels, 2 ppt generally marks the upstream edge of the entrapment zone. Net Delta outflow tends to control the location of the mixing zone and the strengths of both the surface and bottom currents in the entrapment zone. At net Delta outflows of less than 12,000 cubic feet per second (cfs) the entrapment zone usually is located upstream of Suisun Bay and away from any significant shallow water habitats.

A wider array of important habitat parameters appear to affect aquatic species in Suisun Bay compared to the Delta. Salinity, bathymetry and flow patterns vary widely in Suisun and San Pablo bays. In addition, the remaining areas of tidal marshland adjacent to these bays support a diverse aquatic fauna with many species using the many habitat types.

MAJOR FACTORS AFFECTING DELTA FISHES

This recovery plan focusses on seven species of fish on the assumption that management efforts made to benefit the seven species will collectively benefit the entire estuarine ecosystem. The step-down outline that is part of this plan lists and prioritizes actions needed to improve conditions for the seven species. The effectiveness of these actions, however, is predicated on conditions in the estuary returning to previous ecological limits, limits that have been greatly stretched in recent years (associated with decline of the seven species). Because the system is unlikely to return to known historic conditions, ecosystem managers will need to be flexible and learn from past experiences to keep remaining native species from going extinct under continually changing conditions. Some of the factors that may present new challenges are: (1) changes in agricultural water policy, (2) new water projects, (3) Delta levee failures, (4) pollution, (5) introduced species, (6) continued growth of human populations, and (7) climate change. The factors are listed in order of the degree that management decisions can affect them.

Changes in agricultural water policy. About 85% of California's developed water is used for irrigated agriculture. Thus any change in water policy that reduces this use can potentially provide more water for the environment in general and the Delta in particular. One potential change is in the pricing structure of water which could be used to encourage water conservation through better irrigation practices and through switching to less water demanding crops. Another potential change is retirement of marginal agricultural lands, especially those that are likely to become too saline to farm in the near future (e.g., west side, San Joaquin Valley), is the source of trace contaminants (e.g., selenium), or likely to become submerged (Delta islands). Alternatively, changes in water use that increase agricultural demand for water, especially during normally low-demand periods, could reduce water available for in-Delta uses (e.g., flooding of rice fields in winter).

New water projects. Although the era of building large-scale water projects in upstream areas that deplete Delta inflows seems to be largely over, there are projects that could drastically change how the system works. Some proposals are currently undergoing interagency review and others are still on the drawing board. U.S. Fish and Wildlife Service (USFW) is aware of approximately 20 major Central Valley Project (CVP), State Water Project (SWP), or private organization proposals that will result in increased water exports from the Delta, reduce water inflow to the Delta, change the timing and volume of Delta inflow, or increase heavy metal contamination into the Delta (Kanim and Taniguchi 1993). Some examples are: Delta Wetlands, and the South and North Delta Water Management plans currently undergoing consultation. The Delta Wetlands Project would use two Delta islands for water storage, with the water being sold either for south-of-Delta uses or for within-Delta uses (e.g., outflow). The project is of interest because of its pioneering use of Delta islands (many of which are below sea level) for water storage and wetlands and for its potential positive and negative effects on Delta fishes, depending on how the project (or similar projects) is operated.

Delta levee failures. Levees around Delta islands are largely constructed of mud and peat and are subject to failure and subsequent flooding of islands they are supposed to protect. Massive levee collapse as the result of earthquakes and exceptionally high tides and winds would drastically change the hydraulics and salinity regime of the Delta. It also would reduce the amount of fresh water that could be transported across the Delta to the CVP and SWP pumps. The effects of such a collapse on Delta organisms also would be drastic and difficult to predict, beyond saying that a major faunal shift probably would occur, perhaps resulting in extinction of some native species. Deliberate flooding of Delta islands requires reinforced levees and therefore would have much less effect on estuarine conditions and through-Delta water transport than flooding via levee failure.

Contaminants. Little is known about the direct effects of toxic pollutants on the biota of the estuary, including the seven species in this recovery plan. However, the waters of the Bay-Delta estuary receive significant inputs of toxic pollutants annually and the amounts and types are changing constantly. The Aquatic Habitat Institute under contract to the State Water Resources Control Board (1990) estimated that from 2,526 to 17,039 metric tons of pollutants enter the estuary annually through point sources, urban and non-urban runoff, riverine sources, dredging, spills and atmospheric deposition. The pollutants include arsenic, cadmium, chromium, copper, hydrocarbons, lead, mercury, nickel, organochlorines, selenium, silver, tributyltin and zinc. Several of these pollutants are present at concentrations that may have lethal and sublethal toxic effects on aquatic life. In addition, "new" pollutants (such as the pesticide carbofuran) may have unexpected effects, such as episodic (but hard to detect) kills of microcrustaceans that are important in Delta food webs. While there is no clear evidence that toxic pollutants have caused the decline of any of the species in this Recovery Plan, it is quite possible that these pollutants may have contributed to their declines and may impede full recovery.

Introduced species. The Sacramento-San Joaquin estuary is an ecosystem dominated by introduced species from top predators such as striped bass to plankton feeders such as the Asiatic clam, *Potamocorbula amurensis*. New species are arriving constantly, largely through ballast water of ships, and each arrival has the potential to cause a major shift in the food web dynamics of the estuary. Such shifts may drive some native species to extinction or make recovery of depleted species much more difficult. Exactly which exotic species are likely to arrive and become established is impossible to predict. However, as long the introduced species lottery continues to exist, drastic changes in the ecosystem can be expected periodically.

Human population growth. California's population is predicted to increase to 50 million by 2020. Such growth places increasing demands on scarce water. Unless the human population stabilizes, the long-term prospects are problematic for conserving adequate water supplies to maintain declining species, such as the seven featured in this report.

Climate change. In the past decade (1984-1994), California experienced more variability in precipitation than had occurred in the previous century. The result was an extended drought interrupted by a record flood and an exceptionally wet year. Tree ring records indicate that droughts of 20-50 years or longer were common in the past, yet California's water management system is based on the assumption that such extended droughts do not occur. A lengthy drought will severely test society's willingness to continue to provide water for environmental purposes, especially in the Delta, when the agricultural and urban economies are severely stressed because of inadequate water supplies.

SPECIES ACCOUNTS

The core of this Recovery Plan are the accounts for the seven species. Each account has 14 sections, as described below. Except for the sections dealing with recovery, each account (except San Joaquin fall chinook salmon) is a slightly updated and revised version of the accounts in Fish Species of Special Concern for California (Moyle *et al.* 1993). The accounts have been extensively reviewed as part of the original publication and by the Recovery Team.

Status: Summary of the official status of each species. Only the delta smelt is formally listed as a threatened species at the present time, although the splittail is proposed for threatened status. All species are in decline, however.

Recovery potential: This rating follows the USFWS guidelines as specified in the Federal Register (1983, 48 - 184: 43098-43105).

Description: A brief description of the distinguishing features of the species, largely based on Moyle (1976).

Taxonomic relationships: A summary of the taxonomic history of the species and reasons for considering the estuary population as a distinct unit for the purposes of the Recovery Plan.

Distribution: Distribution of the species.

Habitat requirements: Habitat requirements of the species.

Life History: Summaries of basic information on the biology of each species from both published and unpublished information.

Abundance: The best estimates available of current abundance and abundance trends. For splittail, longfin smelt, and delta smelt, trends were determined primarily through the long-term data sets from bottom and midwater trawling of the California Department of Fish and Game (CDFG) and University of California, Davis (UCD). Green sturgeon numbers came from the sturgeon studies of CDFG and from fisheries statistics. Chinook salmon numbers are derived from various counts of adults in the rivers, from juvenile surveys of various sorts, and from other fishery statistics. Numbers for all species from the SWP and CVP fish salvage operations were used to assess affects of project operations in recent years.

Reasons for decline: A summary of reasons for decline, in approximate order of importance.

Conservation measures: A summary of measures currently underway to protect the species.

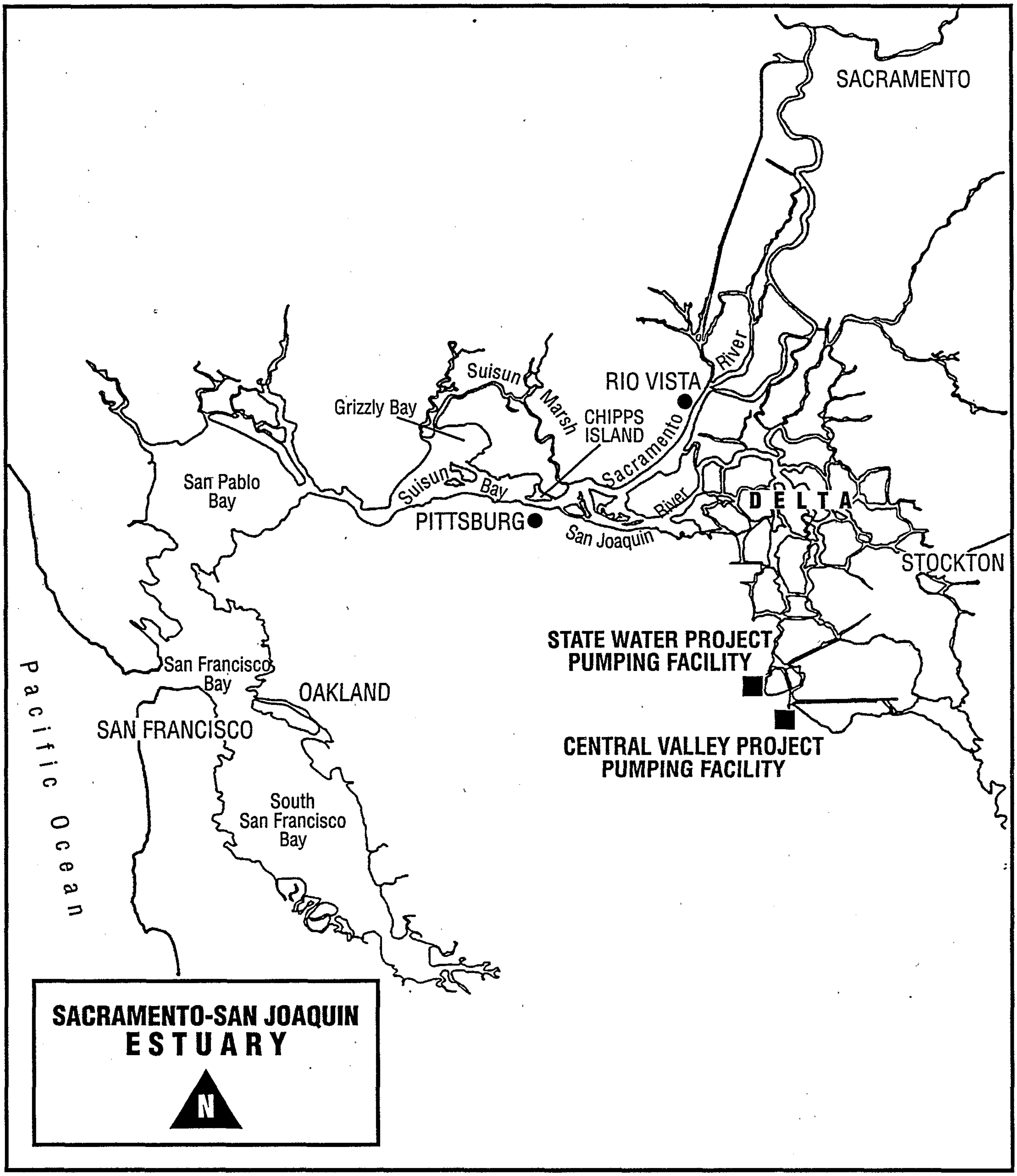
Recovery objective: A short statement of the general objective for restoring populations of the species to sustainable numbers. In general, the recovery objective for each species has to be accomplished in the context of the recovery of other species in the Recovery Plan.

Recovery criteria: The recovery criteria are quantifiable, species-specific criteria that can be used (1) to monitor the effectiveness of recovery actions, (2) to determine when the species has recovered to a secure level (stabilized) and (3) when the species qualifies for delisting (if formally listed). When possible, recovery criteria are based on two independent measures: population abundance and geographic distribution. For each species, a historic base period was established using available data to characterize abundance and distribution during a pre-decline period. Recovery criteria therefore represent historic abundance and distribution patterns, including natural variation in both measures. The time period over which abundance and distribution criteria must be met was set at five generations, based on criteria found in other fish recovery plans.

When a species meets both abundance and distributional criteria for five generations, it will be considered stabilized (recovered) but, if formally listed under the Endangered Species Act, not necessarily eligible for delisting. This will enable quick implementation of additional actions needed to increase protection if ongoing monitoring demonstrates that the species no longer meets recovery criteria after the five-generation period. Species not formally listed should be treated with the same caution.

For a species to be considered for delisting, abundance and distribution criteria must be maintained for a five-generation period. For five of the seven species there is an additional requirement of meeting the criteria through a minimum number of years of stressful environmental conditions. In general, stressful environmental conditions are considered to be those occurring during dry or critically dry years when freshwater outflow from the Delta is substantially reduced. For one species, exceptionally high outflow years may also be considered as stressful. The placement of legal and operational mechanisms to ensure the continuation of favorable conditions may also lead to a consideration of delisting.

Figure 1.1 Map of the Sacramento-San Joaquin estuary.



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2. DELTA SMELT

Hypomesus transpacificus McAllister

Introduction

Status: Endemic species. Federally and State listed as Threatened, 1993.

Recovery potential: 2C[1]. The delta smelt is under a high degree of threat, but it managed to survive the severe 1986-1992 drought in small numbers and rebound to pre-decline levels in 1993 suggesting that its recovery potential is fairly high.

Description: Delta smelt are slender-bodied fish that typically reach 60-70 mm SL, although a few may reach 120 mm SL. The mouth is small, with a maxilla that does not extend past the midpoint of the eye. The eyes are relatively large, with the orbit width contained approximately 3.5-4 times in the head length. Small, pointed teeth are present on the upper and lower jaws. The first gill arch has 27-33 gill rakers and there are 7 branchiostegal rays. The pectoral fins reach less than two-thirds of the way to the bases of the pelvic fins. There are 9-10 dorsal fin rays, 8 pelvic fin rays, 10-12 pectoral fin rays, and 15-17 anal fin rays. The lateral line is incomplete and has 53-60 scales along it. There are 4-5 pyloric caeca. Live fish are nearly translucent and have a steely-blue sheen to their sides. Occasionally there may be one chromatophore between the mandibles, but usually there is none.

Taxonomic Relationships: The taxonomic history of this species is detailed in Moyle (1976). The delta smelt was first considered to be a population of the widely distributed pond smelt, *Hypomesus olidus*. Hamada (1961) recognized pond smelt and delta smelt as different species and renamed the pond smelt *H. sakhalinus*, retaining the name *H. olidus* for delta smelt and wakasagi. McAllister (1963) redescribed delta smelt as *H. transpacificus*, but with Japanese and California subspecies, *H. t. nipponensis* and *H. t. transpacificus*, respectively. Subsequent studies have shown that the two widely separated subspecies should be recognized as species, with delta smelt being *H. transpacificus* and the Japanese species (wakasagi) being *H. nipponensis* (Moyle 1980). Wakasagi were introduced into California reservoirs on the assumption that they were the same species (*H. olidus*) as the delta smelt (Moyle 1976). Electrophoretic studies have demonstrated that wakasagi and delta smelt are genetically very distinct and presumably derived from different marine ancestors (Stanley *et al.* 1993). The genetic differences are great enough so that even introgressive hybridization between the two species is unlikely.

Distribution: Delta smelt are endemic to the upper Sacramento-San Joaquin estuary (Figure 1.1). They occur in the Delta primarily below Isleton on the Sacramento River, below Mossdale on the San Joaquin River, and in Suisun Bay. They move into freshwater when spawning (ranging from January to July) and can occur in the Sacramento River as high as Sacramento, the Mokelumne River system, the Cache Slough region, the Delta, and Montezuma Slough area of the estuary. During high outflow periods, they may be washed into San Pablo Bay, but they do not establish permanent populations there. Since 1982,

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[1]The team originally assigned a 5C recovery priority to delta smelt based on a high degree of threat and low recovery potential due to uncertainty as to the exact cause of decline. One member of the Team ranked delta smelt as 11C because the ability of the species to survive the recent extended drought indicated that the degree of threat to it was "moderate" rather than "high."

the center of delta smelt abundance has been the northwestern Delta in the channel of the Sacramento River. However, high outflows in the winter of 1992-93 allowed delta smelt to recolonize Suisun Bay in 1993 (D. Sweetnam, CDFG, unpublished data). Delta smelt are captured seasonally in Suisun Marsh.

Habitat Requirements: Delta smelt are euryhaline fish that rarely occur in water with more than 10-12 ppt salinity (about 1/3 sea water). Historically, they have been most abundant in shallow areas where early spring salinities are around 2 ppt (3.0 mS/cm) (Figure 2.1). During the recent drought (1987-92), delta smelt were concentrated in deep areas in the lower Sacramento River near Emmaton, where average salinity ranged from 0.36 to 3.6 ppt for much of the year (Figure 2.1) (DWR 1994). During years with wet springs (such as 1993), delta smelt may continue to be abundant in Suisun Bay during summer even after the 2 ppt isohaline has retreated upstream (Sweetnam and Stevens 1993). Fall abundance of delta smelt is generally highest in years when salinities of 2 ppt are in the shallows of Suisun Bay during the preceding spring ($p < 0.05$, $r = 0.50$) (Herbold 1994). Herbold (1994) found a significant relationship between number of days when 2 ppt was in Suisun Bay during April with subsequent delta smelt abundance ($p < 0.05$, $r = 0.49$) (Figure 2.2), but noted that autocorrelations in time and space reduce the reliability of any analysis that compares parts of years or small geographical areas.

Wang (1986) reported spawning taking place in fresh water at temperatures of about 7-15°C. However, ripe delta smelt and recently hatched larvae have been collected in recent years at temperatures of 15-22° C, so it is likely that spawning can take place over the entire 7-22° C range. Temperatures that are optimal for survival of embryos and larvae have not yet been determined, although R. Mager, UCD, (unpublished data) found low hatching success and embryo survival from spawns of captive fish collected at higher temperatures. Delta smelt of all sizes are found in the main channels of the Delta and Suisun Marsh and the open waters of Suisun Bay where the waters are well oxygenated and temperatures relatively cool (usually less than 20-22°C in summer). When not spawning, they tend to be concentrated near the zone where incoming salt water and outflowing freshwater mix (mixing zone). This area has the highest primary productivity and is where zooplankton populations (on which delta smelt feed) are usually most dense (Knutson and Orsi 1983; Orsi and Mecum 1986).

Life History: Delta smelt inhabit open, surface waters of the Delta and Suisun Bay, where they presumably school. Spawning takes place between January and July, as inferred from larvae collected during this period (Wang 1986; Sweetnam and Stevens 1993; D. Sweetnam, CDFG, unpublished data). Timing and length of the spawning season may vary (Figure 2.3). Spawning usually takes place from late March through mid-May in low outflow years. Spawning pulses have not been detected (Wang and Brown 1993). Most spawning occurs in sloughs and shallow edge-waters of channels in the upper Delta and in the Sacramento River above Rio Vista, although it has been recorded in Montezuma Slough near Suisun Bay (Wang 1986) and also may occur in Suisun Slough in Suisun Marsh (P. Moyle, UCD, unpublished data). Delta smelt eggs are demersal and adhesive, sticking to hard substrates such as rock, gravel, tree roots or submerged branches, and submerged vegetation (Moyle 1976; Wang 1986). At 14-16° C, embryonic development to hatching takes 9 -14 days and feeding begins 4-5 days later (R. Mager, UCD, unpublished data). Newly hatched delta smelt have a large oil globule that makes them semi-buoyant, allowing them to maintain themselves just off the bottom (R. Mager, UCD, unpublished data), where they feed on rotifers and other microscopic prey. Once the swimbladder develops, larvae become more buoyant and rise up higher into the water column. At this stage (16-18 mm TL), most are presumably washed downstream until they reach the mixing zone or the area immediately upstream of it. Growth is rapid and juvenile fish are 40-50 mm long by early August (Erkkila *et al.* 1950; Ganssle 1966; Radtke 1966). By this time, young-of-year fish dominate trawl catches of delta smelt, and adults become rare. Delta smelt reach 55-70 mm SL in 7-9 months (Moyle 1976). Growth during the next 3 months slows down considerably (only 3-9 mm total), presumably because most of the energy ingested is being directed towards gonadal development (Erkkila *et al.* 1950; Radtke 1966). There is no correlation between size and fecundity, and females between 59-70 mm SL lay 1,200 to 2,600 eggs (Moyle *et al.* 1992). The abrupt change from a single-age, adult cohort during spawning in spring to a population dominated by juveniles in summer suggests strongly that most adults die after they spawn (Radtke 1966).

In a near-annual fish like delta smelt, a strong relationship would be expected between number of spawners present in one year and number of recruits to the population the following year. Instead, the stock-recruit relationship for delta smelt is weak, accounting for about a quarter of the variability in recruitment (Sweetnam and Stevens 1993). This relationship does indicate, however, that factors affecting numbers of spawning adults (e.g., entrainment, toxics, predation) can have an effect on delta smelt numbers the following year.

Delta smelt feed primarily on planktonic copepods, cladocerans, amphipods and, to a lesser extent, on insect larvae. Larger fish may also feed on the opossum shrimp, *Neomysis mercedis*. The most important food organism for all sizes seems to be the euryhaline copepod, *Eurytemora affinis*, although in recent years the exotic species, *Pseudodiaptomus forbesi*, has become a major part of the diet (Moyle *et al.* 1992). Delta smelt are a minor prey item of juvenile and subadult striped bass, *Morone saxatilis*, in the Sacramento-San Joaquin Delta (Stevens 1966). They also have been reported from the stomach contents of white catfish, *Ameiurus catus*, (Turner and Kelley 1966) and black crappie, *Pomoxis nigromaculatus*, (Turner and Kelley 1966) in the Delta.

Abundance: Delta smelt were once one of the most common pelagic fish in the upper Sacramento-San Joaquin estuary, as indicated by its abundance in CDFG trawl catches (Erkkila *et al.* 1950; Radtke 1966; Stevens and Miller 1983). Delta smelt abundance from year to year has fluctuated greatly in the past, but between 1982 and 1992 their population was consistently low. The decline became precipitous in 1982 and 1983 due to extremely high outflows and continued through the drought years 1987-1992 (Moyle *et al.* 1992). In 1993, numbers increased considerably, apparently in response to a wet winter and spring. During the period 1982-1992, most of the population was confined to the Sacramento River channel between Collinsville and Rio Vista (D. Sweetnam, CDFG unpublished data). This was still an area of high abundance in 1993, but delta smelt were also abundant in Suisun Bay. The actual size of the delta smelt population is not known. Stevens *et al.* (1990) estimated the population size to be about 280,000, but they recognized that this value is based on a tenuous relationship between delta smelt numbers and numbers of young striped bass and is imperfect. However, the pelagic life style of delta smelt, short life span, spawning habits, and relatively low fecundity indicate that a fairly substantial population probably is necessary to keep the species from becoming extinct.

Reasons for decline: The causes of the decline of delta smelt are multiple and synergistic, but seem to be in the following order of importance:

1. <u>Reduction in outflows</u>.

Increased upstream storage and diversion of water from the Sacramento and San Joaquin rivers and tributaries, particularly in combination with dry years, has reduced fresh water available to flush through the estuary (Figure 2.4). Snow fall is also reduced in dry years. Increased diversions when snow melt is low results in reduction of both total outflow and high spring outflows which are important to spawning fish. Diversions also create reverse flows in the lower San Joaquin River, making delta smelt more vulnerable to entrainment (see #2 in this section). For fishes and most other Delta organisms, moderately high spring outflows are important because they cause the mixing zone of the estuary to be located in Suisun Bay. The mixing effect allows phytoplankton, zooplankton, and larval fish to remain in the mixing zone rather than being flushed out to sea. Suisun Bay is broad and shallow, so when the mixing zone is located there nutrients and algae can circulate in sunlit waters, allowing algae to grow and reproduce rapidly (Arthur and Ball 1978; Cloern 1979). This provides food for zooplankton, which are food for plankton-feeding fish such as delta smelt and their larvae. Low outflows place the mixing zone in the deep, narrow channels of the Delta and Sacramento River where productivity of phytoplankton is lower because much of the water is beyond the reach of sunlight. Presumably, if the food supply is inadequate, fish either starve to death or have increased mortality from predation, as a result of slower growth rates.

Strong statistical relationships between outflow and abundances of striped bass, American shad, chinook salmon, longfin smelt, splittail were demonstrated by Stevens (1977), Daniels and Moyle (1980), and Stevens and Miller (1983). Stevens and Miller (1983) failed to find this same relationship for delta smelt. Nevertheless, there is a relationship between outflows and delta smelt abundance (Figure 2.5). Moyle and Herbold (1989) found that lowest delta smelt numbers occurred either in years of low or extremely high outflow, but there was no outflow-abundance relationship at intermediate outflows.

2. <u>Entrainment</u> <u>losses</u> <u>to</u> <u>water</u> <u>diversions</u>.

This factor is closely tied to the first factor because as diversions increase in drier years, there is less fresh water available to transport larval and juvenile fish to Suisun Bay. Water is pumped out of the system through numerous small diversions for Delta farms and large diversions of the Federal Central Valley Project (CVP) and State Water Project (SWP). Water is also pumped through power plants for cooling west of the Delta. Recent analyses by CDFG (1987a; 1992 WRINT-Exhibit 2 and 3) indicate that entrainment of young fish in these diversions has been a major cause of the ongoing decline of striped bass. It is likely that this entrainment loss is also a major factor affecting delta smelt populations, as delta smelt are ecologically similar to larval and juvenile striped bass.

Large numbers of young delta smelt are entrained at CVP and SWP plants just as young striped bass are. Efforts are made to rescue fish being entrained at CVP and SWP plants by trapping them and trucking them back to the Delta. The effectiveness of this procedure has not been well evaluated, but it is unlikely that many delta smelt survive the handling it involves. Experience in capturing and handling the fishes of the estuary indicates that delta smelt are easily stressed and probably die from handling (P. Moyle, UCD, unpublished data). Although it is likely that losses of delta smelt to entrainment are important (especially in dry years), analyses by DWR and CDFG have failed to find a significant relationship between salvage and subsequent abundance of delta smelt (DWR 1993).

When CVP and SWP pumps are operating, delta smelt are also more vulnerable to hundreds of siphons and pumps throughout the Delta that irrigate Delta islands. When larvae are concentrated in the river channels they are more likely to be entrained in major and minor diversions. High export pumping in dry years changes the hydraulics of the Delta such that small fish wind up in Delta channels rather than down in Suisun Bay where they are relatively immune to entrainment. Studies are currently being conducted to quantify losses of delta smelt and other fishes to these diversions. Some delta smelt have been captured in agricultural diversions during the studies, but it appears that season, location and size of the diversion are major factors affecting entrainment of delta smelt (DWR 1993).

Another major diversion within the habitat of delta smelt is the power generation facilities operated by Pacific Gas and Electric Company west of the Delta, near Pittsburg. These facilities entrain large numbers of delta smelt juveniles and larvae. Although larvae entrained in cooling systems are not necessarily lost and some fish of other species may survive, effects on delta smelt, a relatively delicate species, are mostly unknown. However, preliminary studies indicate that 100% mortality of delta smelt takes place at current cooling tower temperatures (T. Swanson, UCD, personal communication).

Several million larval and juvenile delta smelt are estimated as lost in State, Federal, agricultural and cooling diversions each year. Impacts of these diversions contributed to decline of delta smelt and limit potential for full recovery of the species.

3. High outflows.

Years of major delta smelt decline have been characterized not only by unusually dry years with exceptionally low outflows (1987-1991) but also by unusually wet years with exceptionally high outflows (1982, 1986). High outflows presumably flush delta smelt out of the system along with much of the zooplankton. This means that not only is potential spawning stock of delta smelt reduced, but its food supply as well. Furthermore, depletion of established populations of invertebrates and fish may have made it easier for exotic species of copepods, clams, and fish to colonize the estuary (see #4), which may be detrimental to delta smelt.

4. Changes in food organisms.

In recent years, three exotic copepods (*Sinocalanus doerrii* and two species of the genus *Pseudodiaptomus*) have invaded the estuary and increased in numbers while the dominant native euryhaline copepod, *Eurytemora affinis*, has declined. Whether or not this is caused by competition between native and introduced species, by selective predation on the native copepod, or by changes in estuarine conditions that favor the introduced species is not known. CDFG (1987a) studies show that larval striped bass do not feed on *S. doerrii* as much as their abundance would indicate. Apparently, *S. doerrii* can swim faster and therefore avoid predation more easily than *E. affinis* (Meng and Orsi 1991). Feeding by delta smelt larvae probably is affected in ways similar to that of striped bass larvae by this change in zooplankton species, so decreased abundance of native copepods may increase the likelihood of larval starvation. However, juvenile and adult delta smelt can apparently switch to *Pseudodiaptomus forbesi* and attain similar levels of fullness (Moyle *et al.* 1992)

Another potential indirect cause of larval starvation is the recent invasion (1986-87) of the euryhaline clam, *Potamocorbula amurensis*, which is now abundant in Suisun Bay. This clam has reduced phytoplankton populations in the bay with its high filtration rates and dense populations. This clam has obviously not been responsible for delta smelt declines, which began before invasion of the clam, but it may help keep delta smelt populations at low levels by reducing availability of zooplankton for larvae.

Yet another complicating factor is the rise in abundance of the diatom *Melosira*, at some times to the point where it is the most abundant species of phytoplankton. This diatom grows in long chains and is very difficult for zooplankton to graze on; thus the change in composition and abundance of zooplankton may also be tied to the increased importance of this diatom. The causes of increase in *Melosira* are not known, but may be related to an increase in water clarity in recent years.

5. Toxic substances.

The waters of the estuary receive a variety of toxic substances, including agricultural pesticides, heavy metals, and other products of urbanized society. The effects of these toxic compounds on larval fishes and their food supply are poorly known, but there is growing evidence that larval striped bass are suffering direct mortality or additional stress from low concentrations of toxic substances (Bennett *et al.* 1990). There is also evidence that planktonic organisms upon which delta smelt feed may be depleted on occasion by brief aperiodic flushing of high concentrations of pesticides (e.g., carbofuran) through the system (H. Bailey, UCD, personal communication). It is not known if these substances also are affecting delta smelt.

6. Disease, competition, and predation.

There is no evidence that disease, competition, or predation has caused delta smelt populations to decline, despite the abundance of introduced species in the estuary. However, diseases and parasites of delta smelt have never been studied. The effects of predation by fishes such as introduced striped bass or competition from introduced planktivores such as threadfin shad, *Dorosoma petenense*, and inland silverside, *Menidia beryllina*, likewise have not been studied. Although delta smelt has managed to coexist with these species in the past, it is quite possible that at low population levels interactions with them could prevent recovery. In particular, inland silversides are usually collected in areas where delta smelt may spawn and they could be major predators on eggs and larvae. Recently (since 1988), chameleon gobies, *Tridentiger trigonocephalus*, have increased dramatically in the Delta. Adults of this species and yellowfin goby, *Acanthogobius flavimanus*, may prey on delta smelt eggs and larvae and interfere with recovery of the species. However, populations of many other fish species, including striped bass, appear to be depressed in the upper estuary (Moyle *et al.* 1985; Stevens *et al.* 1985; Herbold *et al.* 1992), so a factor affecting just one species is likely to be a secondary cause of decline at best.

In past years, efforts to enhance striped bass populations by planting large numbers of juveniles from hatcheries could have had a negative effect on other pelagic fishes in the estuary. The enhanced predator populations, without a concomitant enhancement of prey populations such as delta smelt, may have resulted in excessive predation pressure on prey species. A particular problem has been the planting of thousands of juvenile striped bass at Rio Vista, near areas where delta smelt have concentrated in recent years. In 1992, planting of juvenile striped bass was halted indefinitely by CDFG because of potential effects of predation on juvenile winter-run chinook salmon and delta smelt.

Most of the species that inhabit the Delta are non-native, including fishes that feed on zooplankton during some life stage. These fishes were introduced over a long-time period and have established themselves with varying degrees of success. There is no evidence, however, that competition for food or space with other aquatic organisms has affected delta smelt populations. Because productivity in the Sacramento-San Joaquin estuary is relatively low compared to other estuaries, food limitation in the estuary may contribute to competition among species, but evidence of this phenomenon has not been documented.

7. Loss of genetic integrity.

Wakasagi, or Japanese pond smelt, were introduced successfully into reservoirs in the Sacramento drainage and subsequently have been collected from downstream areas. Wakasagi are present in Folsom Reservoir and also have been collected in the American River (L. Brown and P. Moyle, UCD, unpublished data) and the Delta (SWP, unpublished data). It is possible that the wakasagi can hybridize with delta smelt, but introgressive hybridization seems unlikely given their great genetic differences (Stanley *et al.* 1993).

Reasons for listing: The reasons for listing a species as threatened or endangered fall into five categories, according to the Endangered Species Act of 1973: "(A) the present, or threatened, destruction, modification, or curtailment of its habitat or range, (B) over-utilization for commercial, recreational, or educational purposes, (C) disease or predation, (D) inadequacy of existing regulatory mechanisms, or (E) other natural or manmade factors affecting its continued existence." All these factors apply, except over-utilization (delta smelt are not harvested).

Modification of habitat is the biggest single reason for listing because both the Delta and Suisun Marsh have been altered by reductions in outflows caused by increased diversion of inflowing freshwater (Section 1, above). Water diversions also result in entrainment losses (Section 2, above). **Disease or predation**, in contrast, are at best minor causes of the listing (Section 6, above). **Other natural or manmade factors** that affect its continued existence include exceptionally high outflows (Section 3), changes in food organisms (Section 4), toxic substances (Section 5) and loss of genetic integrity (Section 7). Because delta smelt prefer shallow water (Moyle *et al.* 1992) and use shallow, vegetated habitat for spawning, the decrease in fresh- and brackish-water floodable marshlands in recent decades probably also contributed to the general decline.

Inadequacy of existing regulatory mechanisms is a factor which contributes to all of the above direct threats to continued existence of delta smelt. The State agency with the most ability to regulate the estuarine environment is the State Water Resources Control Board (SWRCB), which has consistently set standards that fail to protect delta smelt and other delta organisms. The recent history of this regulatory inadequacy is as follows:

1978. SWRCB adopted Decision 1485, which set comprehensive water quality standards for the Delta, even though USFWS Stated that this would result in maintaining fish and wildlife at a "degraded level." The principal measure of success of the standards was an index of striped bass abundance (minimum SBI = 79).

1980. USEPA approved the D-1485 standards on the condition that SWRCB adopts additional standards as necessary to protect the estuary, under its obligations through the Clean Water Act.

1981. In the first triennial review of the water quality standards, USEPA urged SWRCB to revise the standards "to protect the Delta fishery." SWRCB did not do so.

1985. In the second triennial review of the water quality standards, USEPA again expressed concern about the inadequacy of SWRCB standards. The SWRCB agreed the standards are inadequate but failed to adopt new ones. The SBI dropped to record lows (1.2 in 1983, 2.2 in 1985).

1986. The State Court of Appeals in San Francisco affirmed SWRCBs obligation to protect fish and wildlife resources of the estuary, among other findings relating to the Board's regulatory obligations.

1987. USEPA indicated it could no longer approve of the SWRCB's D-1485 standards but agreed to take no action until hearings on new standards were completed. During the hearings, testimony was given that the delta smelt is in serious decline.

1988. SWRCB issued new draft standards that would substantially improve conditions in the estuary.

1989. The draft standards were withdrawn by SWRCB. This was the third year of drought and yet the State Water Project pumped record amounts of water through the Delta. The State Fish and Game Commission refused to list the delta smelt as a threatened species, despite the recommendation of the Department of Fish and Game that they should do so.

1991. SWRCB adopts a water quality control plan that does not provide for critical salinity or flow protections. USEPA disapproved of the plan in that it did not provide adequate protection of the estuary.

1992. SWRCB held another series of hearings and released draft Decision 1630 that presented interim water quality standards. While D-1630 offered substantial improvements in environmental quality above the D-1485 standards, USEPA indicated the proposed standards were still inadequate.

1993. SWRCB withdraws D-1630. EPA issues its own proposed standards after threatened with a lawsuit from 16 environmental groups for not complying with the Clean Water Act.

In addition to this extended series of interactions by SWRCB and USEPA, other regulatory failures were also evident. New species of organisms continued to invade the estuary, introduced from the unregulated dumping of ballast water by ships. Toxic compounds continued to enter estuarine food webs, resulting in probable mortalities to fish larvae and small crustaceans and resulting in health warnings about consumption of fish from the estuary.

Conservation measures: The State Water Resources Control Board recognized the need for more outflows to protect native fishes and other "public trust resources" in their proposed Decision 1630, which recommended increased outflows and a variety of other measures to protect fish. The decision was not implemented because of the controversial nature of the proposed actions, not because fisheries declines were widely disputed. The Bay-Delta Oversight Committee was appointed by Governor Pete Wilson to develop alternative solutions to the problem of declining fish populations. Ultimately, solutions will have to be adopted by SWRCB because USEPA has proposed, under the Clean Water Act, water quality standards for the estuary. These standards, if adopted and implemented by the SWRCB, should offer considerable protection to delta smelt and other fishes.

The Central Valley Project Improvement Act of 1992 makes protection of fish one of the goals of the CVP and dedicates part of the project's water to conservation; presumably some of this water will be used to enhance conditions in the estuary for delta smelt and other native fishes.

Endangered species consultations with NMFS (winter-run chinook salmon) and USFWS (delta smelt) have occurred for CVP Operations Criteria and other projects. Recommended actions, such as reduced pumping by the CVP and SWP and screening of diversions, should also be beneficial to delta smelt and other native species.

Table 2.1A and 2.1B list Federal actions that will affect delta smelt. Section 7(a)(2) of the Endangered Species Act of 1978, as amended, requires Federal agencies to consult with the USFWS or the National Marine Fisheries Service on the potential adverse effects of projects on listed species. Section 10(a) of the Endangered Species Act requires State and private entities proposing projects that may take a listed species to provide a Conservation Plan that minimizes incidental take. "Take" is defined as any action that may harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct with a listed species.

On January 6, 1994, USFWS has proposed designation of critical habitat of delta smelt to include all of Suisun Bay and the Delta (Figure 2.6). The designation of critical habitat requires analysis and possible modifcations of all habitat-altering activities taking place within the region. The official description reads as follows:

"Areas of all water and all submerged lands below ordinary high water and the entire water column bounded by and contained in Suisun Bay (including the contiguous Grizzly and Honker bays); the length of Montezuma Slough and the existing contiguous waters contained within the Delta, as defined by section 12220, of the State of California's Water Code (a complex of bays, dead-end sloughs, channels typically less than 4 meters deep, marshlands, etc. as follows:

Bounded by a line beginning at the Carquinez Bridge which crosses Carquinez Strait, thence northeasterly along the western and northern shoreline of Suisun Bay, including Goodyear, Suisun, Cutoff, First Mallard (Spring Branch), and Montezuma sloughs; thence upstream to the intersection of Montezuma slough with the western boundary of the Delta as delineated in Section 12220 of the State of California's Water Code of 1969; thence following a boundary and including all contiguous water bodies contained within the statutory definition of the Delta, to its intersection with the San Joaquin River at its confluence with Suisun Bay; thence westerly along the south shore of Suisun Bay to the Carquinez Bridge."

As a back-up measure, delta smelt culture techniques and facilities are being developed. Initial efforts to breed delta smelt in captivity have been successful, although rearing beyond the larval stage so far has not been possible (R. Mager, UCD, unpublished data). However, if hatchery propagation is to be successful, fish must be released into an environment that provides ample food, low levels of toxic compounds, and low entrainment losses.

Ongoing research on delta smelt includes studies of distribution, abundance, spawning habits, cohort analysis, effects of toxics and predation. Researchers are developing procedures for separating delta, longfin and wakasagi smelt, including taxonomic keys and electrophoretic work. Work is being done on losses of delta smelt to diversions and on improving fish handling at water project diversions. Models are being developed of delta smelt population dynamics and persistence. Investigations are being conducted on delta smelt reproductive cycle, gametogenesis and environmental tolerance to changes in salinity, temperature and flow.

RECOVERY

Objective

The objective of this part of the Delta Native Fishes Recovery Plan is to remove delta smelt from the Federal list of threatened species through restoration of its abundance and distribution. Recovery of delta smelt should not be at the expense of other native fishes. The basic strategy for recovery is to manage the estuary in such a way that it is a better habitat for native fish in general and delta smelt in particular. Improved habitat will allow delta smelt to be widely distributed throughout the Delta and Suisun Bay, recognizing that areas of abundance change with season. Recovery of delta smelt will consist of two phases, recovery and delisting. Separate recovery and delisting periods were identified because it is possible that recovery criteria can be met fairly quickly in the absence of consecutive extreme outflow years (i.e., extremely wet or dry years). However, without the population being tested by extreme outflows there is no assurance of long-term survival for the species. Thus, recovery is defined as a return of the population to pre-decline levels, but delisting is not recommended until the population has been tested by extreme outflows. Delta smelt will be eligible for recovered status when its population dynamics and distribution pattern within the estuary are similar to those that existed in the **1967-1981** period. This period was chosen because it includes the earliest continuous data on delta smelt abundances and was a period in which populations stayed reasonably high in most years (see below for a more detailed justification). The species will qualify for delisting when it goes through a five-year period that includes two sequential years of extreme outflows, one of which must be dry or critically dry. Delta smelt will be eligible for delisting when the species meets recovery criteria under stressor conditions comparable to those that led to listing and mechanisms are in place that insure the species' continued existence.

Recovery Criteria

Recovery of delta smelt should be assessed when the species satisfies distributional and abundance criteria. Distributional criteria include catches of delta smelt in all zones 2 of 5 consecutive years, in at least two zones in 1 of the remaining 3 years, and in at least one zone for the remaining 2 years. Abundance criteria are: delta smelt numbers must equal or exceed 239 for 2 out of 5 years and not fall below 84 for more than two years in a row. Distributional and abundance criteria can be met in different years. If abundance and distributional criteria are met for a five-year period the species will be considered recovered. Delta smelt will be considered for delisting when abundance and distributional criteria are met for a five-year period which includes two successive extreme outflow years, with one year dry or critical. Delisting is contingent on the placement of legal mechanisms and interagency agreements to manage the CVP, SWP, and other water users to meet these criteria. Both criteria depend on data collected by CDFG during the Fall Midwater Trawl Survey (FMWT), during September and October.

Justification for using FMWT numbers: The FMWT covers the entire range of delta smelt distribution and provides one of the two best measures of delta smelt abundance (Sweetnam and Stevens 1993). The summer tow-net survey samples juveniles of this annual species and provides another good measure of abundance. The FMWT provides a better measure of abundance because it samples pre-spawning adult delta smelt. An index based on pre-spawning adults, rather than on juveniles which are vulnerable to high mortality, provides a better estimate of delta smelt stock and recruitment.

September and October numbers of adults were chosen, because these are the months that were sampled most consistently in all years. In addition, when delta smelt begin moving upstream to spawn in November and December they occur less frequently in the FMWT. Weather conditions are also more stable in September and October. The more frequent storms of November and December produce conditions that result in more variability in fish-capture numbers. There is a high correlation between September and October numbers and total numbers (r = 0.93).

Delta smelt numbers rather than the abundance index was used for recovery criteria. The abundance index was initially developed for striped bass. Numbers were chosen because delta smelt occupy the upper water column. Multiplying delta smelt captured by volume of water sampled probably doesn't give a good representation of the number of fish present. Using numbers for delta smelt simplifies the assumptions of the criteria and there is a close correspondence between numbers and the abundance index for delta smelt (r=0.89).

Justification for using 1967-1981 for the standard: Graphs from different surveys were used to establish pre-decline and post-decline periods for delta smelt (Moyle *et al.* 1992). The surveys included were the FMWT, summer tow-net, Suisun Marsh fish survey and the bay survey (Appendix A). Each of the surveys showed slightly different patterns of decline. The most noticeable trend is that delta smelt decline began earlier in the south and east Delta than in the rest of the estuary (Sweetnam and Stevens 1993). The pre-decline period identified by Moyle *et al.* (1992) is 1967 through and including 1981; the post-decline period is 1982-92. Using 1982 as the beginning of the decline period is justified because 1982 and 1983 were very wet years and declines in delta smelt abundance correspond to extremes in outflow: very dry and very wet years result in low numbers (Moyle *et al.* 1992). The mechanisms for this are that delta smelt larvae are washed downstream of favorable nursery grounds in wet years; dry years decrease spawning habitat and move adults and juveniles upstream into less productive deep river channels where they are more at risk to entrainment in water projects.

Other alternatives were proposed for the decline period. One possibility was to use 1981 as the beginning of the decline period because it was a dry year followed by the wet year 1982. The occurrence of a dry year followed by a wet year produces a double stress on delta smelt and this may have been the true beginning of the decline. An argument can also be made for using 1983 as the beginning of the decline; this is the year that delta smelt declined in the FMWT and so is consistent with other recovery criteria (which is based on the FMWT). There is a noticeable change in geographic distribution of delta smelt in 1982 and 1983 which corresponds to the periods used in the Biological Opinion and the decline in FMWT numbers, respectively. The decline in delta smelt numbers actually occurred over a multi-year period from 1981-1983; the midpoint of this period, 1982, was used as the beginning of the decline.

Justification for including distributional recovery criteria: Geographical distribution was used as well as numbers of fish to measure recovery because recovery of delta smelt should include a restoration of the species to their former range. Before 1982 delta smelt were captured at an average of 19 FMWT stations; after 1981 they were captured at an average of 10 stations. From 1986-1992 the delta smelt population was concentrated in the lower Sacramento River between Collinsville and Rio Vista (Sweetnam and Stevens 1993). Historically, when delta smelt were more abundant, the population was spread from Suisun Bay and Montezuma Slough through the Delta. The shallow, productive waters of Suisun Bay and Suisun Marsh are important habitat for delta smelt. Large percentages of delta smelt catches are in Suisun Bay when outflows are sufficient to maintain the mixing zone and salinities of 2-3 ppt in that area. When delta smelt are concentrated in deep river channels due to high salinities in Suisun Bay they are more vulnerable to entrainment in water project facilities, predation and other risks.

FMWT Stations chosen to measure recovery: The stations chosen for the recovery criteria had to be sampled in every year (that the FMWT was conducted) and had to have a record of delta smelt catches. This was modified somewhat by including stations that were sampled in all years but one (stations 509, 511, 602). The total number of stations is 35 and there is a strong correlation between delta smelt at these stations and total numbers of delta smelt (r = 0.94).
The stations are (Figure 2.7):

Zone A (North Central Delta)
11 stations
802 804 806 808 810 812 814 903 904 906 908

Zone B1 (Sacramento River)
5 stations
701 703 705 707 709

Zone B2 (Montezuma Slough)
4 stations
602 604 606 608

Zone C (Suisun Bay)
15 stations
410 412 414 416 418 501 503 505 507 509 511 513 515 517 519

Distributional criteria: Distributional criteria were developed on the basis of number of stations in each zone where delta smelt were captured during the pre-decline period (Tables 2.2, 2.3, Figures 2.7 and 2.8). For each zone the criteria are as follows: 1) in Zone A delta smelt must be captured in 2 of 11 sites; 2) in Zone B (includes B1 and B2) delta smelt must be captured in 5 of 9 sites; and 3) in Zone C delta smelt must be captured in 6 of 15 sites. The criteria for all zones do not need to be met in all years. Criteria for recovery are as follows: the site criteria must be met in all zones 2 of 5 consecutive years, in at least two zones in 1 of the remaining 3 years, and in at least one zone for the remaining 2 years. A failure in all zones in any year will result in the start of a new 5-year evaluation period for the distributional criteria. Failure to meet these criteria in consecutive years should be avoided because such conditions will place the species in danger of extinction. These distributional criteria will be met in concert with the abundance criteria.

Abundance criteria: The abundance of delta smelt that will constitute recovery is based on pre-decline delta smelt numbers from the FMWT (Table 2.3). Two numbers were identified that had to be met during the five-year recovery period: a low number below which abundance can not fall for more than two years in a row and a high number to be reached or exceeded in two out of five years. A low number was chosen to protect delta smelt from the risk of extinction during prolonged droughts or extremes of outflow. The lowest two-year running average of abundance in the pre-decline years was used for the low number. A running average was used because of the great degree of variability in delta smelt abundance. The high number is the median of delta smelt abundance in pre-decline years, in other words, abundance of delta smelt half of the time in the pre-decline period. To meet recovery criteria, delta smelt abundance must meet or exceed 239 in two out of five years and the two-year running average must never fall below 84. If any of these conditions are not met, the five-year recovery period will start again.

Length of recovery and delisting period: Delta smelt generation time and frequency of occurrence of very dry and very wet years were used to determine appropriate length of the recovery period. Because delta smelt live only a year, a five-year recovery period would include five generations of delta smelt; five generations is comparable to the period used in recovery plans for other fishes. A five-year recovery period has a reasonable probability of including years with extreme outflow. The 40:30:30[2] Sacramento River Indices (SRI) from 1906-1992 was used for this analysis. The goal was to identify a period that had a high probability of including two extreme outflow years, preferably back-to-back. This method was chosen because when two extreme years occur together delta smelt are at risk of extinction. Because extremes in outflow led to the listing of the delta smelt, the period identified for delisting differs from recovery and includes a stressor period. Delta smelt will be delisted when abundance and distributional criteria have been met over a five-year period that includes two sequential years of extreme outflows. One of the extreme years must be dry or critically dry (SRI $\leq$ 6.0); the other can be wet SRI $\geq$ 11.2). Other indices can be used to identify dry, critically dry and wet years, if appropriate. Dry conditions are included because delta smelt losses increase in dry and critical years due to high proportions of outflow diverted which results in habitat loss and increased entrainment in water projects. Analysis of the historical hydrograph indicated that there is about a 24% chance that two extreme years (one being dry or critical) will occur in a five-year period. There is a 48% chance (based on the historical hydrograph) that the period of time required to delist delta smelt could be 10 years. According to existing records, the longest amount of time required to delist delta smelt is 38 years.

[2]Year-type categories adopted by the SWRCB in the 1991 Salinity Control Plan.

Table 2.1A. Examples of actions that set precedents for protecting delta smelt by building on previous decisions and providing incremental protection to the Delta.

(1) Water Rights Decision 1485 by the State Water Resources Control Board, 1978

(2) National Marine Fisheries Service formal long-term biological opinion on the effects of the CVP and SWP on winter-run chinook salmon for the U.S. Bureau of Reclamation and California Department of Water Resources, February 12, 1993

(3) U.S. Fish and Wildlife Service formal biological opinion on the effects of the CVP and SWP on delta smelt for the U.S. Bureau of Reclamation and California Department of Water Resources, May 26, 1993

(4) U.S. Fish and Wildlife Service formal biological opinion on the effects of the Los Vaqueros Project on delta smelt for the U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, and Contra Costa Water District, September 9, 1993

(5) U.S. Fish and Wildlife Service biological opinion on the effects of the CVP and SWP on delta smelt for the U.S. Bureau of Reclamation and California Department of Water Resources, February 4, 1994

Table 2.1B. Examples of future actions with potential effects on delta smelt

(1) Delta Wetlands Project proposed by Delta Wetlands Corporation requiring U.S. Army Corps of Engineers permit

(2) South Delta Water Management Plan by U.S. Bureau of Reclamation and California Department of Water Resources

(3) North Delta Water Management Plan by California Department of Water Resources requiring U.S.Army Corps of Engineers permit

(4) Suisun Marsh Water Management Plan by U.S. Bureau of Reclamation and California Department of Reclamation requiring U.S. Army Corps of Engineers permit

(5) Pacific Gas and Electric Company Habitat Conservation Plan for U.S. Fish and Wildlife Service

(6) Bay-Delta Water Quality Standards by U.S. Environmental Protection Agency

C-048401

Table 2.2 Number of sites with delta smelt from FMWT September and October numbers for 35 stations. Numbers in brackets refer to station numbers. The FMWT did not sample in 1974 and 1979. See Figure 2.8 for how minimum number of sites was determined.

		Sites	
Year	Zone C Suisun Bay (410-519)	Zone B Montezuma Slough Sacramento River (602-709)	Zone A North Central Delta (802-908)
		Pre-decline	
1967	6	8	2
1968	9	6	8
1969	11	7	0
1970	12	8	7
1971	13	8	8
1972	12	8	9
1973	9	9	4
1975	12	5	5
1976	1	5	2
1977	0	5	5
1978	11	6	0
1980	10	8	3
1981	8	6	0
Minimum number of sites	6 of 15	5 of 9	2 of 11
Number of years minimum number of sites occurred	11 out of 13	13 of 13	10 of 13
		Post-decline	
1982	6	6	1
1983	5	4	0
1984	9	3	0
1985	2	3	0
1986	10	5	1
1987	2	4	1
1988	3	3	0
1989	6	5	3
1990	4	6	0
1991	4	6	3
1992	0	5	1
1993	12	6	4
Number of years minimum number of sites occurred	5 out of 12	7 out of 12	3 out of 12

Table 2.3 Numbers used for delta smelt abundance criteria. Numbers are from the September and October FMWT for 35 stations. The FMWT did not sample 1974 and 1979.

Year	Number	Two-year running average
	Pre-decline	
1967	139	
1968	251	195
1969	128	190
1970	589	359
1971	352	471
1972	551	452
1973	305	428
1975	239	272
1976	22	131
1977	146	84
1978	108	127
1980	312	210
1981	78	195
	Post-decline	
1982	37	58
1983	17	27
1984	51	34
1985	29	40
1986	70	50
1987	72	71
1988	43	58
1989	76	60
1990	81	79
1991	171	126
1992	26	98
1993	300	199

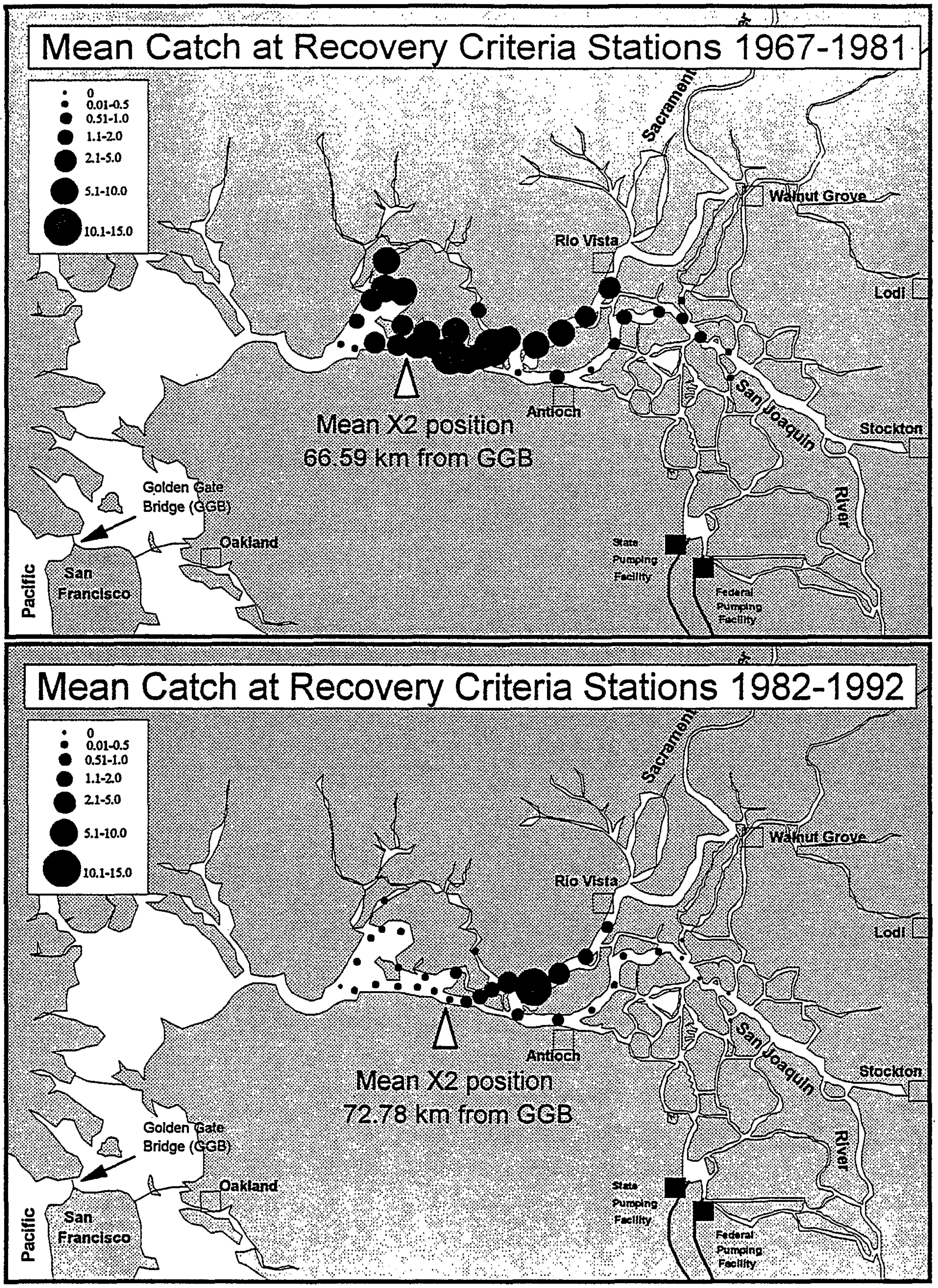


Figure 2.1 Pre- and post-decline distribution of delta smelt. The position of the mixing zone is denoted by X2.

Correlations with Five km Reaches

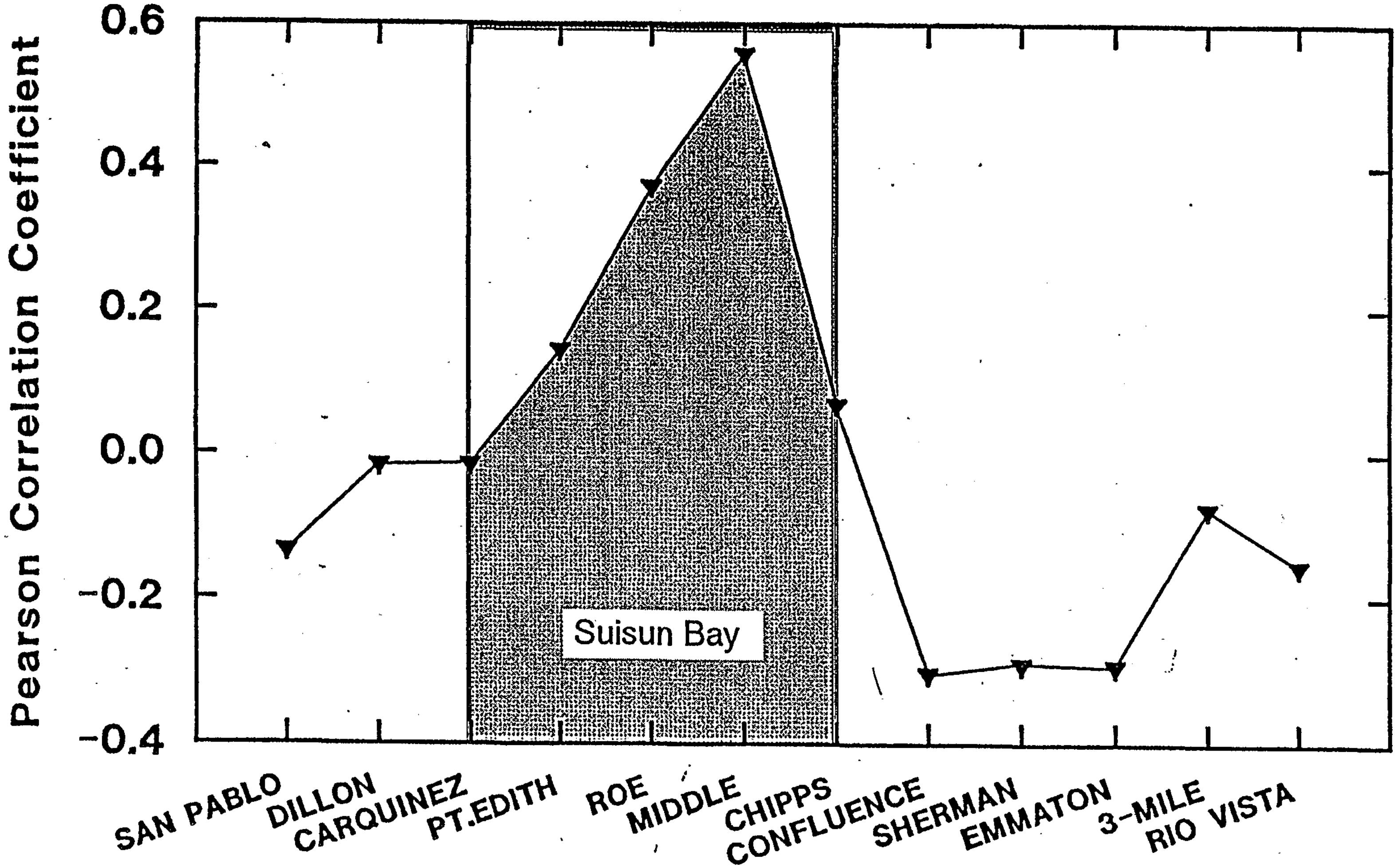
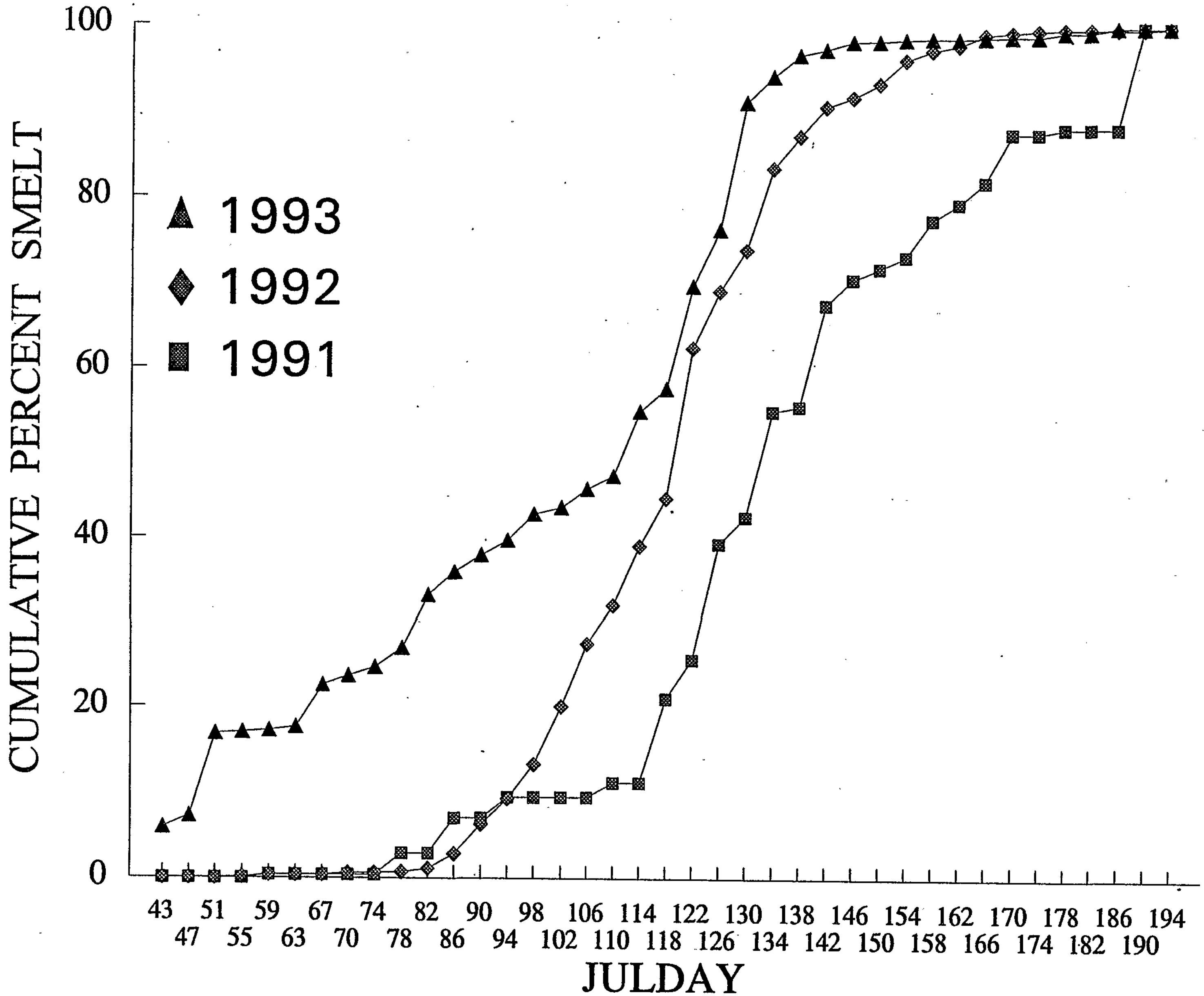


Figure 2.2 Relationship between number of days when 2ppt is in Suisun Bay during April with subsequent delta smelt abundance.



1991-93 Delta smelt larva, prejuvenile, and juvenile temporal distribution expressed as cumulative percent

Figure 2.3 Spawning times of delta smelt 1991-3, expressed as percent cumulative larvae. Julday = January 1.

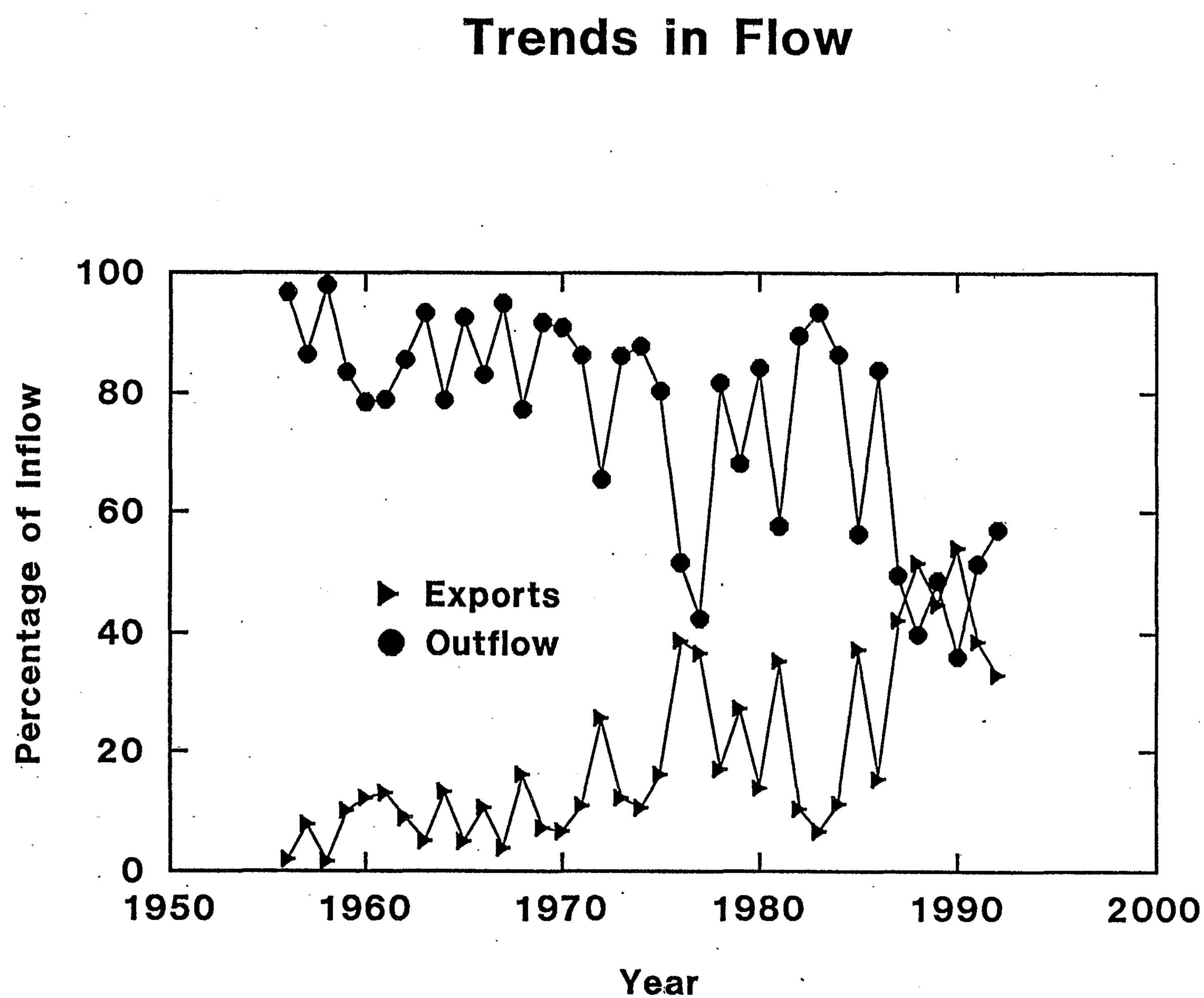


Figure 2.4 Trends in flow.

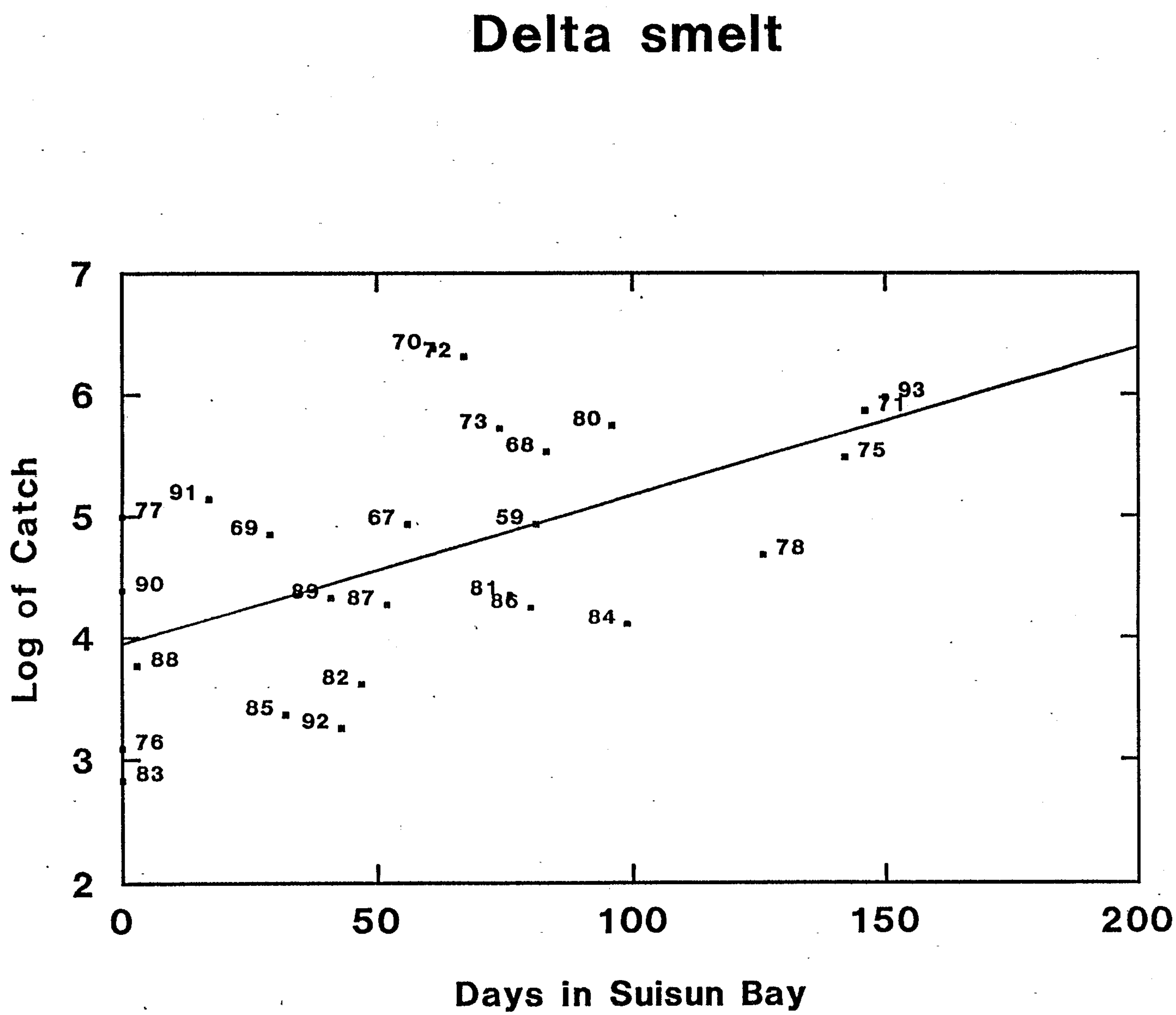


Figure 2.5 Relationship between outflow and delta smelt abundance. Days in Suisun Bay refers to the number of days that 2ppt is in Suisun Bay.

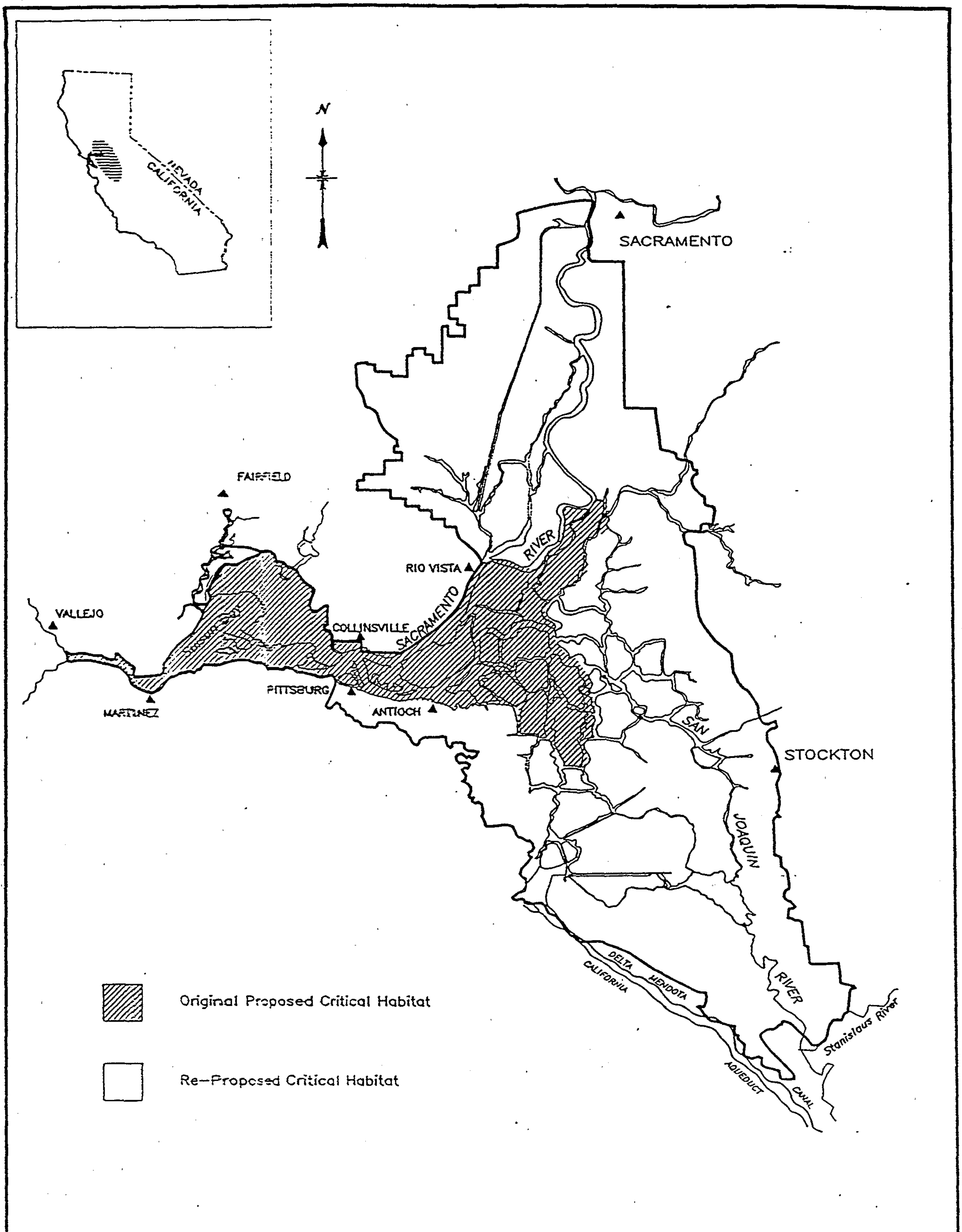


Figure 2.6 Delta Smelt critical habitat.

Delta Smelt Recovery Criteria Stations

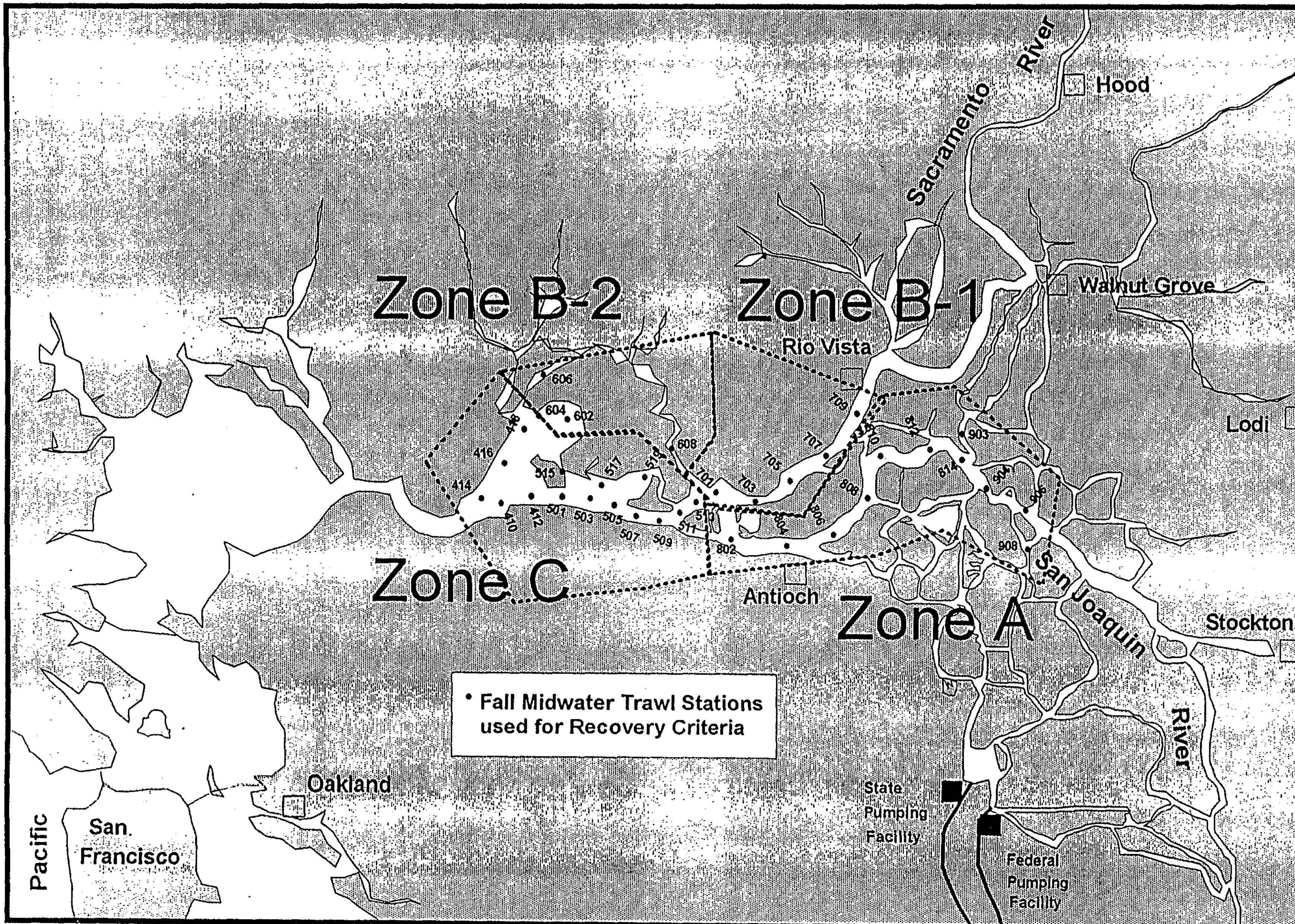


Figure 2.7 Delta smelt recovery critèria stations.

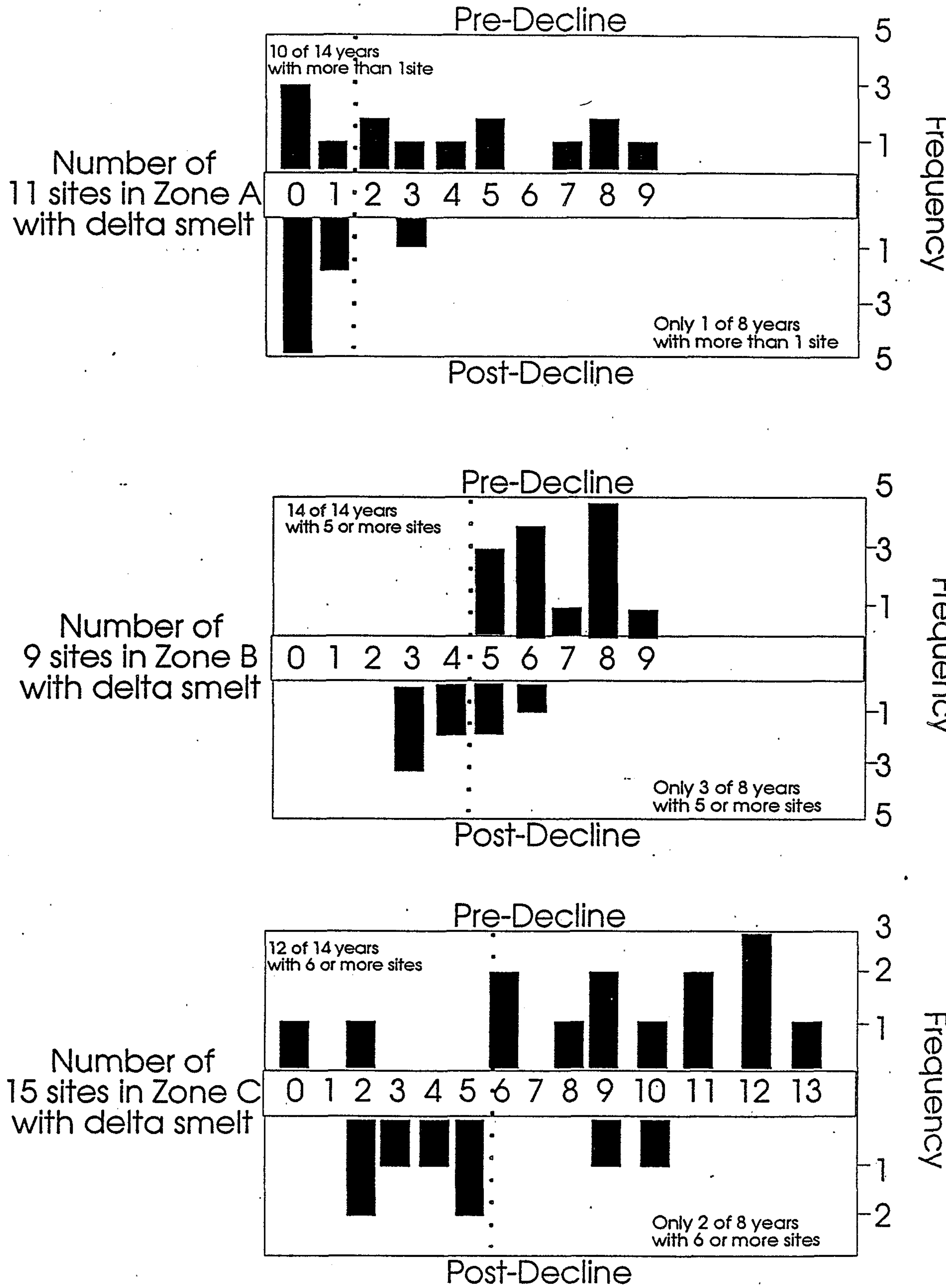


Figure 2.8 Number of sites with delta smelt pre- and post-decline.

3. LONGFIN SMELT

Spirinchus thaleichthys (Ayres)

Introduction

Status: Longfin smelt is a category 2 candidate species.

Restoration potential: While the degree of threat to this species is high, its restoration potential also is high, because of its potential to respond strongly to increased outflows. However, in 1993 (a wet year) longfin smelt numbers were below predicted abundance.

Description: Longfin smelt can be distinguished from other California smelts by their long pectoral fins (which reach or nearly reach the base of the pelvic fins), incomplete lateral line, weak or absent striations on the opercular bones, low number of scales in the lateral series (54-65), and long maxillary bones (which in adults extend just short of the posterior margin of the eye). The lower jaw projects forward of the upper when the mouth is closed. Small, fine teeth are present on both jaws, tongue, vomer and palatines. The number of dorsal rays is 8-10; anal rays, 15-22; pectoral rays, 10-12; gill rakers, 38-47; and pyloric caeca, 4-6. The orbit width goes into the head length 3.6-4.5 times, and the longest anal rays 1.4-2.2 times into the head length (McAllister 1963; Miller and Lea 1972; Morrow 1980). The lining of the gut cavity is silvery with a few scattered speckles. The sides of living fish appear translucent silver while the back has an olive to iridescent pinkish hue. Mature males are usually darker than females, with enlarged and stiffened dorsal and anal fins, a dilated lateral line region, and breeding tubercles on the paired fins and scales (McAllister 1963).

Taxonomic Relationships: The longfin smelt belongs to the true smelt family Osmeridae. Its closest relative in California is the night smelt, *Spirinchus starksi*. A third *Spirinchus* species, *S. lanceolatus*, occurs in northern Japanese waters and differs from *S. thaleichthys* in several morphological characters and in timing of spawning (McAllister 1963). The longfin smelt was at one time considered to be two species: the Sacramento smelt (*S. thaleichthys)* in the Sacramento-San Joaquin estuary and the longfin smelt (*S. dilatus)*, for the rest of the populations. McAllister (1963) merged the two species because he thought the meristic characters separating the Sacramento smelt from the other populations represented the southern end of a north-south cline in the characters, rather than a discrete set. This analysis was confirmed by the electrophoretic study of Stanley *et al.* (1993), which showed only minor differences in allele frequencies between longfin smelt populations in Lake Washington (Washington) and those in San Francisco Bay. The differences were sufficient, however, to demonstrate no recent gene flow between the two populations. The longfin smelt population in the Sacramento-San Joaquin estuary is very isolated from other populations; the closest is in Humboldt Bay, which is ca. 300 km away by sea (and may now be extinct). Also this population is the southernmost of the species. It is similar in this respect to a recognized run of chinook salmon (e.g., winter-run chinook) and fits the definition of an Evolutionarily Significant Unit established by the National Marine Fisheries Service (Waples 1991).

Distribution: Historically, populations of longfin smelt in California have been present in the Sacramento-San Joaquin estuary, Humboldt Bay, the Eel River estuary, and the Klamath River estuary. Spawning longfin smelt have been recorded from the Van Duzen River in the Eel River drainage, and a sample from there is in the museum collection at Humboldt State University. There are also recent records from the mouth of the Klamath River, so it is likely that a small population still exists there (R.

Baxter, CDFG, personal communication). In the Sacramento-San Joaquin estuary, longfin smelt are rarely found upstream of Rio Vista or Medford Island in the Delta. Adults occur seasonally as far downstream as South Bay but they are concentrated in Suisun, San Pablo, and North San Francisco bays. They are rarely collected outside the estuary. The southernmost record of the species range is a single fish from Monterey Bay (Eschmeyer *et al.* 1983, Wang 1986), but probably only individuals flushed out of the Sacramento-San Joaquin estuary occur that far south.

Outside of California, longfin smelt are reportedly found in estuaries from Oregon to Prince William Sound, Alaska. Emmett *et al.* (1991) inferred that longfin smelt were common in Skagit Bay, Grays Harbor and Willapa Bay in Washington, highly abundant in the Columbia River, and common in Yaquina and Coos bays, Oregon. However, most of the Oregon and Washington inferences are not based on actual sampling and may contradict the results of field programs. For example, longfin smelt have rarely been collected in Coos Bay in the past 20 years despite intensive fish sampling programs (D. Varoujean, Oregon Institute of Marine Biology, personal communication). Landlocked populations occur in Lake Washington, Washington, and Harrison Lake, British Columbia (Dryfoos 1965).

Habitat Requirements: Adult and juvenile longfin smelt occupy mostly the middle or bottom of the water column in the salt or brackish water portions of the estuary, although larval longfin smelt are concentrated in near-surface brackish waters (R. Baxter, personal communication). Spawning takes place in fresh water, over sandy-gravel substrates, rocks, and aquatic plants (Wang 1986; Emmett *et al.* 1991). Spawning in the Sacramento-San Joaquin estuary occurs at water temperatures of 7.0-14.5°C (Wang 1986), although spawning occurs at lower temperatures in other areas, such as Lake Washington (Emmett *et al.* 1991). There is a strong positive correlation between winter-spring Delta outflow and longfin smelt abundance in fall of the same year. The reason for this seems to be that higher flows increase the rate of transport and dispersal of larvae and juveniles into rearing habitat in Suisun and San Pablo bays. High flows also reduce the probability of the larvae being retained in the Delta, where they are exposed to greater likelihood of entrainment, exposure to pesticides, and other factors. However, the positive relationship between longfin smelt abundance and outflow may have broken down in recent years, or dropped to a lower level (as occurred for striped bass). The catch of longfin smelt in the fall midwater trawl surveys since 1984 has consistently been lower than would be predicted by the regression equation of catch versus outflow during 1967-1984 (Figure 3.1). The catches for 1989, 1991, and 1992 occurred outside the 95% confidence interval. The index for 1993 (a wet year) was back within the confidence interval but was still lower than the predicted value.

High freshwater outflows also increase the volume of brackish water (2-18 ppt salinity) rearing habitat required by larval and juvenile longfin smelt (R. Baxter, CDFG, unpublished data). Because the life history of longfin smelt is similar in many respects to that of striped bass, it is likely that longfin smelt larvae, like striped bass larvae, have higher survival rates in brackish water (Hall 1991). Adults occur in the open waters of the estuary at salinities ranging from fresh water to full sea water. In most years, adults are found primarily in Suisun, San Pablo, and San Francisco bays. However, they are most abundant in San Pablo and Suisun bays, although in low outflow years they concentrate in Suisun Bay and the Delta. Average summertime salinities in Suisun Bay normally were < 8 ppt even in dry years prior to the longfin smelt decline. In San Pablo Bay salinities are typically < 25 ppt.

Life History: Longfin smelt generally are euryhaline and anadromous. In the Sacramento-San Joaquin estuary, the usual seaward limit for longfin smelt is central San Francisco Bay, although some have been caught offshore (R. Baxter, personal communication). In the estuary, adults and juveniles can be found in water ranging from nearly pure sea water to completely fresh water. The preference of larval longfin smelt for the upper part of the water column allows them to be swept quickly into food-rich nursery areas downstream, mainly Suisun and San Pablo bays. During years when periods of high outflows coincide with the presence of the larval longfin smelt (e.g., 1980, 1982, 1983, 1984, 1986), the larvae are mostly transported to Suisun and San Pablo bays while in years of lower outflow, they are transported to the western Delta and Suisun Bay (Figure 3.2). The distribution of young-of-year longfin smelt largely coincides with that of the larvae. In the winter months, yearlings become more widely distributed downstream, with some even colonizing South Bay, although they remain most abundant in San Pablo and Suisun bays.

During the fall, the distribution of yearling longfin smelt gradually shifts upstream, a change which coincides with development of the gonads in preparation for spawning. They congregate for spawning at the upper end of Suisun Bay and the lower and middle Delta in the Sacramento River channel and adjacent sloughs. This distribution pattern may represent a change from the historic pattern. The CDFG fall midwater trawl data indicates that longfin smelt were scarce in the Sacramento River and the Delta prior to 1977 (a second year of drought); after 1977 they became more common in the upstream catches (Table 3.1). The reasons for this shift are uncertain.

Larval longfin smelt are generally collected below Medford Island in the San Joaquin River and below Rio Vista on the Sacramento River (Wang 1991), indicating that spawning rarely occurs above these locations. The lower end of the spawning habitat seems to be upper Suisun Bay around Pittsburg and Montezuma Slough, in Suisun Marsh (Wang 1986). The longfin smelt has a rather protracted spawning period. Adult movements and the presence of larvae in some December plankton samples indicate that some spawning may take place as early as November (R. Baxter, unpublished data) while larval surveys indicate spawning may occur into June (Wang 1986, 1991). Most spawning takes place from February through April, because larval longfin smelt are most abundant in this period and large smelt become rare after this time. Both one and two year old males and females can spawn but most females spawn when two years old. However, mature females have been collected at sizes as small as 64 mm FL and when two year old fish are scarce in the population, as in 1993, a majority of the spawning longfin smelt may be yearlings (R. Baxter, personal communication). Wang (1986) indicates that older and larger longfin smelt spawn later in the season than smaller ones. In Washington, males evidently precede the females in the spawning run upriver (Wydoski and Whitney 1979), and spawning occurs at night. It is not known if this behavior also characterizes Sacramento longfin smelt. The eggs are adhesive (Dryfoos 1965) and are deposited either on rocks or on aquatic plants. Each female lays 5,000-24,000 eggs (Dryfoos 1965, Moyle 1976.). However, the mean number for ten females from Lake Washington was 18,104 (Dryfoos 1965), which is higher than recorded for California populations (mean = 9752, Moyle, unpublished data). The eggs hatch in 40 days at 7°C (Dryfoos 1965). Apparently, most longfin smelt die after spawning. A few individuals, mainly one year old females, live another year, and probably spawn a second time (R. Baxter, personal communication).

Newly hatched longfin smelt larvae are 5-8 mm long (Wang 1991). Metamorphosis into the juvenile form probably begins 30-60 days after hatching, depending on temperature (Emmett *et al.* 1991). Larvae and early juveniles tend to concentrate in the upper part of the water column but at around 20 mm they may drop down into deeper water (R. Baxter, personal communication). Growth in California populations is similar to that of more intensively studied Washington populations (Dryfoos 1965). Most growth in length takes place in the first nine to ten months of life, when the fish typically reach 60-70 mm SL. Growth rate levels off during the first winter, but there is another period of growth during the second summer and fall, when the fish reach 90-110 mm SL. Weight gains may be considerable during this latter period as the gonads develop. The largest longfin smelt are 120-140 mm SL, presumably females in their third year of life.

The main food of longfin smelt is the opossum shrimp, *Neomysis mercedis*, although copepods and other crustaceans are important at times, especially to small fish (Dryfoos 1965, Moyle 1976). Longfin smelt, in turn, are eaten by a variety of predatory fishes, birds and marine mammals. They are a major prey of harbor seals, *Phoca vitulina*, in the Columbia River (Emmett *et al.* 1991).

In the landlocked Lake Washington population in Washington, adult longfin smelt show daily vertical migrations, moving into deep water during the day and in the upper water column at night (Wydoski and Whitney 1979, Emmett *et al.* 1991). This may explain why juvenile and adult longfin smelt are usually captured in trawls in the lower half of the water column in the Sacramento-San Joaquin estuary (R. Baxter, unpublished data), where most sampling takes place during the day.

Longfin smelt are caught and marketed incidentally with other smelt species (Wang 1986). They are of only minor commercial importance, evidently because the supply is sporadic and the amounts caught are relatively small. However, it is likely that they were an important component of the smelt fishery that existed in the estuary in the late 19th century.

Abundance: Longfin smelt populations declined by 90% between 1984 and 1992 in the Sacramento-San Joaquin estuary (Meng 1993, Figure 3.3) and apparently have disappeared in recent years from the Eel River estuary and from Humboldt Bay on the north coast.

In the Sacramento-San Joaquin estuary, longfin smelt were once one of the most abundant fish. The CDFG fall midwater trawl survey of the upper estuary, the CDFG otter and midwater trawl Bay surveys, and the UCD Suisun Marsh surveys consistently caught longfin smelt in large numbers until the early 1980s (Herbold *et al.* 1992). The numbers of longfin smelt fluctuated widely, reaching their lowest levels during drought years but quickly recovering when adequate winter and spring flows were once again present. Since 1982, longfin smelt numbers have plummeted and have remained at record low numbers (Herbold *et al.* 1992). For example, in 1982, the fall midwater trawl abundance index for longfin smelt was 62,929, the second highest on record; in 1992, the index was 73, the lowest on record. The fall index in 1993 (792) increased in response to the increased outflows but was still below the numbers that would be predicted based on the past outflow-abundance relationship (R. Baxter, personal communication). The longfin smelt has declined in relative abundance to other fishes, dropping from being first or second in abundance in most trawl surveys during the 1960s and 1970s to being 7th or 8th in abundance (Herbold *et al.* 1992).

In Humboldt Bay, Barnhart *et al.* (1992) noted that in the early 1970s, longfin smelt were the third most abundant species in larval fish surveys and fourth most abundant fish in trawl surveys. On the basis of these studies they list longfin smelt as "abundant" in the bay and important as forage fishes. However, no longfin smelt have been collected from the bay in recent years despite extensive sampling of the estuary (R. Fritzsche, Humboldt State University, personal communication). Likewise, there are no recent records from the Eel River estuary (L. Brown, USGS, personal communication). Longfin smelt are apparently still present in the Klamath River estuary but confirmed records are few (R. Baxter, personal communication). There seem to be no recent confirmed records of longfin smelt from estuaries along the Oregon coast until the Columbia River estuary, which supports a large population.

Reasons for decline: The longfin smelt has clearly undergone a severe decline in the Sacramento-San Joaquin estuary, while the two closest populations (Eel River and Humboldt Bay) have apparently gone extinct. The causes of the disappearance of longfin smelt in the latter two estuaries may be related to a dramatic loss of intertidal marsh habitat that resulted in lower productivity and less shallow spawning habitat (Barnhart *et al.* 1992). Loss of shallow, vegetated habitat has also affected the Delta population. The causes of the decline in the Sacramento-San Joaquin estuary are multiple and synergistic and include the following, in approximate order of importance:

1. <u>Reduction in outflows</u>

Reduction in outflow, as a result of a recent drought and through water diversions upstream of, from, and within the Delta, is probably the single biggest factor affecting longfin smelt abundance in the

Sacramento-San Joaquin estuary. To demonstrate the effects of diversions a regression equation, included in the listing petition, related longfin smelt numbers to Delta outflow ($p < .01$, B. Herbold, USEPA, personal communication). This equation predicts that mean spring (February-May) outflows much less than 3400 cfs will result in reproductive failure of longfin smelt. Such flows for two or three years in a row would probably result in extinction of longfin smelt in the estuary. Between 1987 and 1993, outflows were perilously close to that number, pushed there by an increase in water diversion during a period of extended drought (see section 4). This has resulted in extremely low numbers of longfin smelt being produced (Figure 3.3). The strong correlation between spring outflow and longfin smelt abundance, and the mechanisms explaining that close relationship, are further documented in CDFG testimony presented during 1992 to the State Water Resources Control Board in the Interim Water Rights Proceedings for the Bay-Delta Estuary (Exhibit WRINT-DFG-6, "Estuary Dependent Species", at pp. 50-61).

Since 1989, however, the abundance of longfin smelt has been consistently lower than would be predicted by the past relationship between abundance and outflow. Analysis of the decline over the last ten years shows that the increasing quantity of water exported during a time when the quantity of water in the State was low has been associated with a continuous decline in longfin smelt capture rates. In earlier, wetter years the quantity of exports was a small fraction of the total Delta inflow and outflow. In recent drought years (1987-1992) the amount of water exported has exceeded the amount flowing into the Bay and capture rates of longfin smelt have declined as total Delta outflow has been correspondingly reduced. This amplification of normal drought effects has been compounded by the ability of upstream reservoirs to retain more of the winter-spring runoff because the reservoirs have been below flood control limits. This further reduced Delta outflow during the time longfin smelt are spawning and their larvae are rearing. This may have exacerbated the normal drought year decline of this species (Figure 3.3), contributing to the breakdown of the outflow-abundance relationship.

2. Entrainment losses to water diversions.

One of the effects of decreased outflows in the estuary is increased vulnerability of longfin smelt of all sizes to entrainment in the pumping plants of CVP and SWP, in agricultural diversions within the Delta, and in the PG & E power plants.

The effects of direct entrainment of longfin smelt in the two pumping plants is not well understood because of limited information of what proportion of the population at each life stage is entrained and the survival rates of the fish that are salvaged and returned to the Delta. Although large numbers of adult longfin smelt are captured at the pumping plants, it is unlikely many individuals of this species survive the experience (actual survival rates have not been documented). If they do, many are probably consumed by piscine and avian predators attracted to the predictable commotion of trucks releasing fish.

Entrainment indices (the ratio of salvaged fish in a particular year and the subsequent abundance index) for the Skinner (SWP) and Tracy (CVP) fish facilities indicate that exports at the two pumping plants tend to take a higher fraction of the longfin smelt population when abundance is low, in dry years (Figure 3.4). Because entrainment increases when populations are low, losses to pumping plants may be a significant source of mortality for longfin smelt.

Entrainment of fish larvae in agricultural diversions within the estuary is largely unquantified. Presumably, entrainment in Delta agricultural diversions was a fairly constant source of mortality for 50-100 years, until flows across the Delta increased because of increased pumping by the SWP and CVP. These facilities not only pump more water than formerly but they pump water earlier in the year, when longfin smelt are spawning and their larvae are present. The changed hydraulics increase the exposure of larval, juvenile, and adult longfin smelt to in-Delta entrainment, predation, and other factors. In their 1992 testimony to the State Water Resources Control Board, the US Bureau of Reclamation stated "...the negative impact of Delta diversions on the fisheries and food chain is largely a consequence of the flow patterns (hydrodynamics) resulting from Delta inflow and CVP/SWP exports. Consequently, any proposed solution must address this important issue if it is to be effective in the long term (WRINT-USBR-Exhibit 10, p. 8)."

The importance of entrainment of longfin smelt, especially larvae, in the cooling water of power plants is not well known. However, the potential for entraining large proportions of the population is considerable, especially now that numbers are low.

3. Climatic variation

The climatic conditions that the estuary has experienced since 1982 have been some of the most extreme since the arrival of Europeans. The years 1985-1992 were ones of continuous drought, broken only by the record outflows of February 1986. The prolonged drought had two major interacting effects: a natural decrease in outflow and an increase in the proportion of inflowing water being diverted. A natural decline in longfin smelt numbers would be expected from the reduced outflow, because of the reduced availability of brackish water habitat for larvae and juveniles. However, the increase in diversions most likely exacerbated the decline in longfin smelt survival through a combination of further reduction in brackish water habitat and increased entrainment of larvae, juveniles, and adults. It is important to recognize that extreme floods and droughts have occurred in the past and longfin smelt have managed to persist through them. However, unlike today, longfin smelt historically did not experience the extreme conditions caused by increased diversion of water.

4. Toxic substances

Pollution is an insidious problem in the estuary because toxic compounds, especially pesticides, can come from many sources, may be episodic in nature (and therefore hard to detect), and may affect mainly early life history stages of fish, where mortality is hard to observe. It is not known what effects toxic substances may have on longfin smelt populations. Longfin smelt spawn early in the season when fewer agricultural chemicals are being applied and flows for dilution may be high. However, agricultural pesticides are applied during the winter time (mainly dormant sprays). Elevated concentrations or pulses of these chemicals have been detected in the Sacramento and San Joaquin rivers following rainfall events. In February, 1993, a pulse of diazinon (a water soluble dormant spray applied to stonefruit orchards) was followed down the Sacramento River, through Suisun and San Pablo bays (Kuivila 1993). It is possible that such episodic high concentrations of chemicals may have negative effects on longfin smelt if the episodes coincide with major spawning times. The short life span and plankton feeding habits (short food chain) of longfin smelt reduce the probability of accumulation of toxic materials in tissues.

5. Predation

Predation is a poorly understood but potentially important factor affecting longfin smelt abundance. The principal piscivore in the estuary is striped bass. This species was introduced over 100 years ago, replacing native piscivores such as Sacramento perch and various salmonids. The longfin smelt remained abundant despite the explosion of striped bass numbers and in recent years the longfin smelt decline has coincided with the decline of striped bass. Therefore, it is unlikely that striped bass predation per se is responsible for the decline of the longfin smelt. However, it has been suggested that striped bass predation in Clifton Court Forebay may be having some effect on longfin smelt populations. Fish are drawn into this forebay by water drawn toward SWP pumps and both predator and prey may be concentrated as a consequence.

6. Introduced species

Invasions by exotic species are a perpetual problem in the Sacramento-San Joaquin estuary, especially those that are introduced into the system "accidentally" from the ballast water of ships. The most recent problem introductions have been several species of planktonic copepods and an Asiatic clam, *Potamocorbula amurensis*. The copepods are regarded as a problem because they seem to be replacing *Eurytemora affinis*, a native copepod that has been the favored food of larval fish. Although one of the introduced copepod species *(Sinocalanus doerrii)* seems to be harder for larval fish to capture, it occurs mostly upstream of the concentrations of longfin smelt larvae. It may only be a problem if diversions keep longfin smelt larvae in upstream, freshwater conditions. Other introduced copepod species probably do not present the capture problems of *S. doerrii* (e.g., Meng and Orsi 1991). The Asiatic clam, in contrast, may have a direct effect on longfin smelt populations because it has become extremely abundant in San Pablo and Suisun bays, from which it appears to be filtering out most of the planktonic algae, the base of the food web on which longfin smelt depend (Nichols *et al.* 1990; Alpine and Cloern 1992).

The clam is not, however, a direct cause of the initial decline of longfin smelt because it did not invade until after February 1986, after the longfin smelt decline had begun (Nichols *et al.* 1990). Its present abundance may make the restoration of longfin smelt more difficult but it is possible that the Asiatic clam will become less abundant in response to (1) increased freshwater outflows, and (2) discovery of it as a food source by fishes such as sturgeon, by invertebrates such as the invading European green crab, and by diving ducks. A typical pattern for invading species is to increase explosively in response to optimal conditions at the time of invasion (due to the absence of their predators, parasites, etc.) and then to decline as the local ecosystem adjusts to its presence, although such an adjustment may take many years.

Conservation measures: Since the delta smelt was listed as a threatened species in 1993, consultations with the USFWS have occurred for the Central Valley Project Operations Criteria and Plan and for the proposed Los Vaqueros Project. Recommended actions (e.g., reduced pumping, screening of diversions) to protect delta smelt also should be beneficial to longfin smelt, although differences between the two smelt species in distribution within the estuary and in spawning times may make these actions less beneficial to longfin smelt than delta smelt. For a more general discussion of conservation measures refer to the delta smelt section.

Research on the biology of longfin smelt and on factors limiting their abundance is now underway (R. Baxter, personal communication).

RESTORATION

Objective

General restoration objectives are the same as those described for delta smelt. Longfin smelt will be eligible for restored status when its population dynamics and distribution pattern within the estuary are similar to those that existed in the **1967-1984** period. This period was chosen because it includes the earliest continuous data on longfin smelt abundances and was a period in which populations stayed reasonably high in most years (see below for a more detailed justification).

Restoration Criteria

Restoration of longfin smelt should be assessed when the species satisfies distributional and abundance criteria. Distributional criteria are: longfin smelt must be captured in all zones 5 of 10 years, in two zones for an additional year, and at least one zone for 3 of the 4 remaining years, with no failure to meet site criteria in consecutive years. Abundance must be equal to or greater than predicted abundance for 5 of 10 years. Distributional and abundance criteria can be met in different years. If abundance and distributional criteria are met for a ten-year period the species will be considered restored. Both criteria depend on data collected by CDFG during the Fall Midwater Trawl Survey (FMWT), during September and October.

Justification for using FMWT numbers: The FMWT covers most of the range of longfin smelt distribution and provides one of the best measures of longfin smelt abundance (R. Baxter, personal communication).

September and October numbers were chosen, because these are the months that were sampled most consistently in all years. Weather conditions are also more stable in September and October. The more frequent storms of November and December produce conditions that result in more variability in fish-capture numbers. There is a high correlation between September and October numbers and total numbers ($r = 0.95$).

Longfin smelt numbers rather than the abundance index were used for restoration criteria. Using numbers for longfin smelt simplifies the assumptions of the criteria and there is a close correspondence between numbers and the abundance index for longfin smelt ($r = 0.94$). Furthermore, use of numbers reduces confusion; the public is familiar with the overall abundance index, but restoration criteria are derived from of a subset of the data, so the restoration index will differ from the overall index.

Justification for using 1967-1984 for the standard: Graphs from different surveys were used to establish pre-decline and post-decline periods for longfin smelt (CDFG and P. Moyle, unpublished data). The surveys included were the FMWT, summer tow-net, Suisun Marsh fish survey and the bay survey.

Justification for including distributional restoration criteria: Geographical distribution was used as well as numbers of fish to measure restoration because restoration of longfin smelt should include a restoration of the species to their former range. Before 1985 longfin smelt were captured at an average of 19 stations; after 1985 they were captured at an average of 8 stations. After 1985 there was an upstream shift in the longfin smelt population due to an upstream shift in the mixing zone (R. Baxter, unpublished data). Historically, when longfin smelt were more abundant, the population was spread from San Pablo to Suisun bays. Upstream excursions into the Delta were only associated with dry years. When longfin smelt are concentrated in the river channels and Delta they are more vulnerable to entrainment in water project facilities (Meng 1993) as shown by high entrainment indices[2] in dry years (DWR, unpublished data).

FMWT Stations chosen to measure restoration: The stations chosen for the restoration criteria had to be sampled in every year (that the FMWT was conducted) and had to have a record of longfin smelt catches. This was modified somewhat by including stations that were sampled in all years but one (stations 509, 511, 602). The total number of stations is 32 and there is a strong correlation between longfin smelt at these stations and total numbers of longfin smelt.
The stations are (Figure 3.5):

Zone A (North Central Delta)
3 stations
802 804 806
Zone B1 (Sacramento River)
5 stations

[2]The entrainment index was developed by DWR to show relative effects of entrainment on different species. It is the ratio of expanded fish salvage numbers to the FMWT index.

701 703 705 707 709
Zone B2 (Montezuma Slough)
4 stations
602 604 606 608
Zone C (Suisun Bay)
16 stations
405 410 412 414 416 418 501 503 505 507 509 511 513 515 517 519
Zone D (San Pablo Bay)
4 stations
321 323 328 338

Distributional criteria: Distributional criteria were developed on the basis of number of stations in each zone where longfin smelt were captured during the pre-decline period (Table 3.1, Figures 3.5 and 3.6). Zones A and B1 (North Central Delta and the Sacramento River) were excluded from the distributional criteria because presence of longfin smelt in these zones does not contribute to restoration. Longfin smelt only occur in Zones A and B1 during dry and critical years when longfin abundances are very low and when they are in these zones they are vulnerable to entrainment (Meng 1993). For each zone the criteria are as follows: 1) in Zone B2 longfin smelt must be captured in 2 of 4 sites; 2) in Zone C longfin smelt must be captured in 12 of 16 sites; and 3) in Zone D longfin smelt must be captured in 1 of 4 sites. The criteria for all zones do not need to met in all years. Criteria for restoration are as follows: the site criteria must be met in all zones 5 of 10 years, in two zones for an additional year, with no failure to meet site criteria in consecutive years, and in at least one of the zones for 3 of the 4 remaining years. These distributional criteria will be met in concert with the abundance criteria.

Abundance criteria: The abundance of longfin smelt that will constitute restoration is based on pre-decline longfin smelt numbers from the FMWT. Because there is a strong relationship between longfin smelt abundance and spring outflow ($r^2 = 0.66$), abundance criteria was based on the February-May outflow-longfin smelt abundance regression, using a subset of FMWT stations. The equation for the regression is: number of longfin smelt captured by the FMWT equals 1.64 times February-May outflow minus 10.6 ($Y = 1.64X - 10.6$). Both number of longfin smelt and February-May outflow are base-ten logs. From 1987-1993 the actual numbers of longfin smelt taken by the FMWT has fallen below the abundance predicted by this relationship. From 1987-1992, longfin smelt abundance dropped by 50% each year (Meng 1993). Therefore longfin smelt abundance must be equal to or greater than that predicted by the above equation for 5 of 10 years of the restoration period to satisfy restoration criteria.

Length of restoration: Longfin smelt generation time was used to determine appropriate length of the restoration period. Because longfin smelt live for two years, a ten-year restoration period would include five generations of longfin smelt; five generations is comparable to the period used in recovery plans for other fishes. Because longfin smelt decline occurred during a six-year period of very low outflows, the population should not be considered restored until it has been tested by consecutive dry or critical years. There is a 48% chance that the ten-year restoration period will include two consecutive years of extreme outflows (see Delta smelt section). Based on the historical hydrograph, the longest amount of time necessary to restore longfin smelt is 38 years.

Table 3.1 Number of sites with longfin smelt from FMWT September and October numbers for 32 stations. Numbers in brackets refer to station numbers. The FMWT did not sample in 1974 and 1979. See Figure 3.6 for how minimum number of sites was determined.

	Sites		
Year	Zone D San Pablo Bay (321-338)	Zone C Suisun Bay (405-519)	Zone B2 Montezuma Slough (602-608)
		Pre-decline	
1967	4	16	3
1968	1	14	4
1969	2	15	4
1970	3	13	3
1971	3	12	3
1972	0	7	2
1973	1	15	4
1975	1	12	3
1976	0	2	2
1977	0	0	0
1978	2	16	3
1980	4	15	4
1981	1	14	3
1982	4	16	4
1983	2	9	2
1984	2	16	3
Minimum number of sites	1 of 4	12 of 16	2 of 4
Number of years minimum number of sites occurred	13 out of 16	12 out of 16	15 out of 16
		Post-decline	
1985	0	6	2
1986	2	15	4
1987	0	11	0
1988	0	7	1
1989	0	3	0
1990	0	2	3
1991	0	1	0
1992	0	2	2
Number of years minimum number of sites occurred	1 out of 8	1 out of 8	4 out of 8

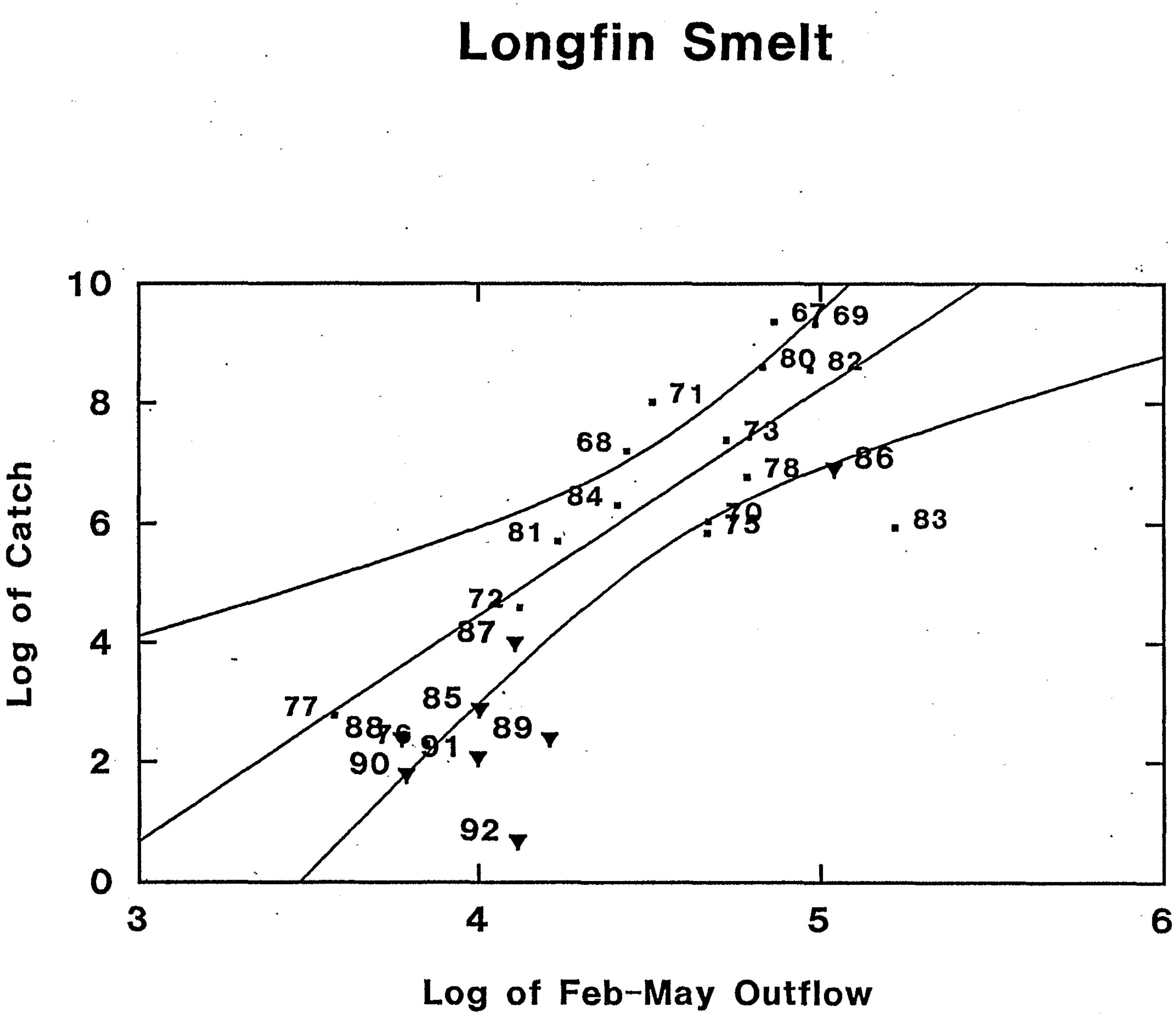


Figure 3.1 Longfin smelt abundance versus outflow (1967-1984).

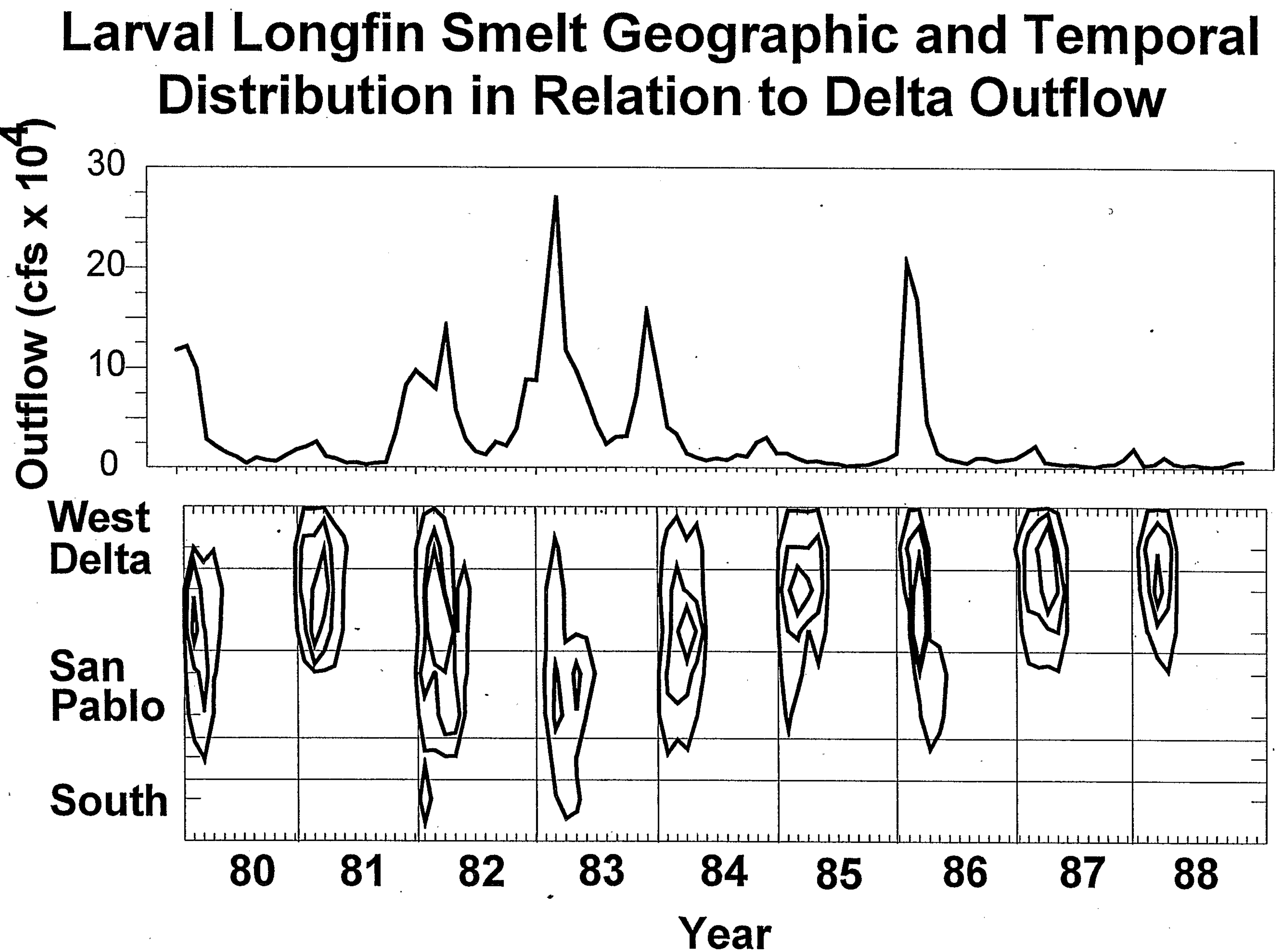


Figure 3.2 Distribution of larval longfin smelt abundance and outflow.

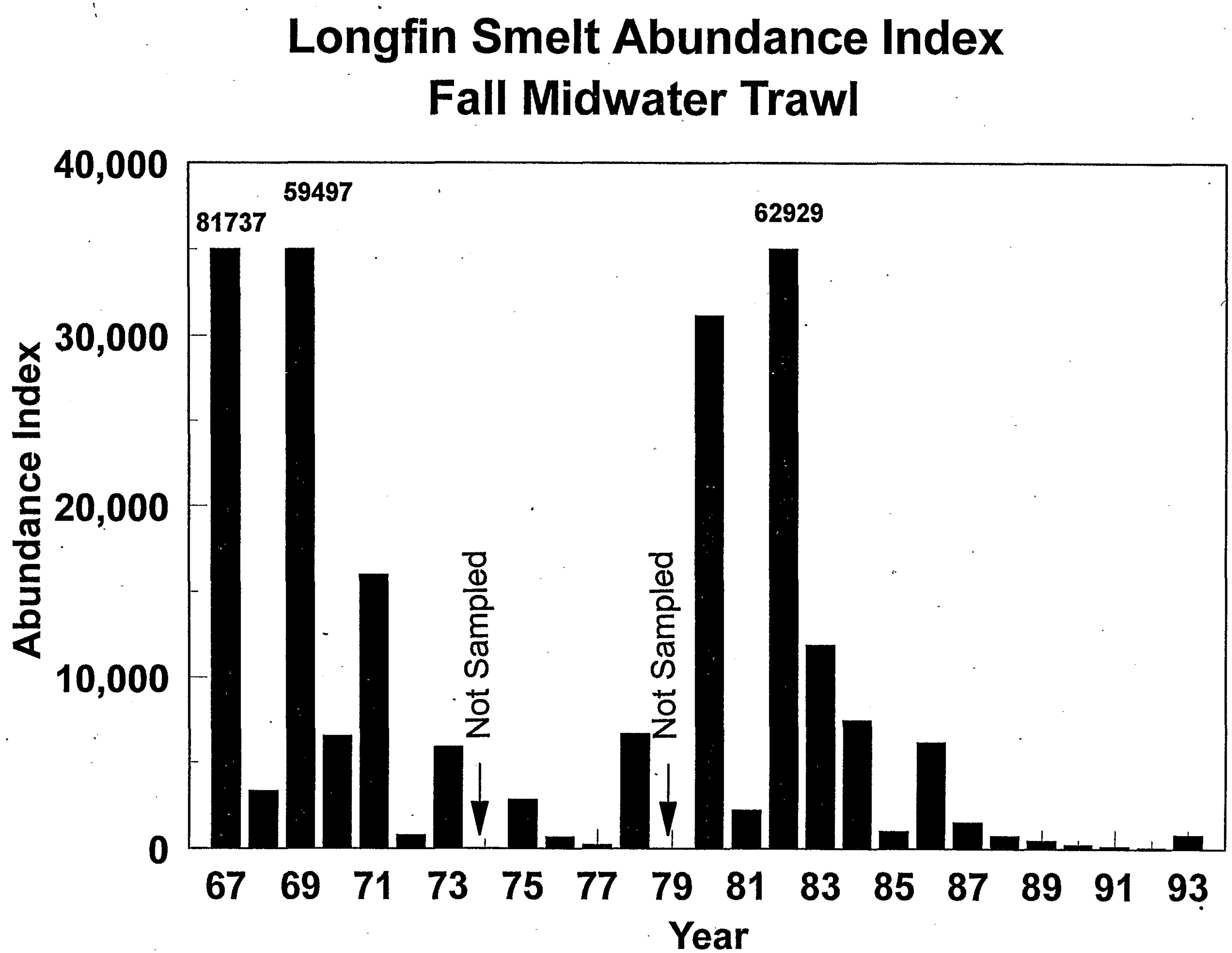


Figure 3.3 Longfin smelt abundance in the FMWT versus year.

LONGFIN SMELT

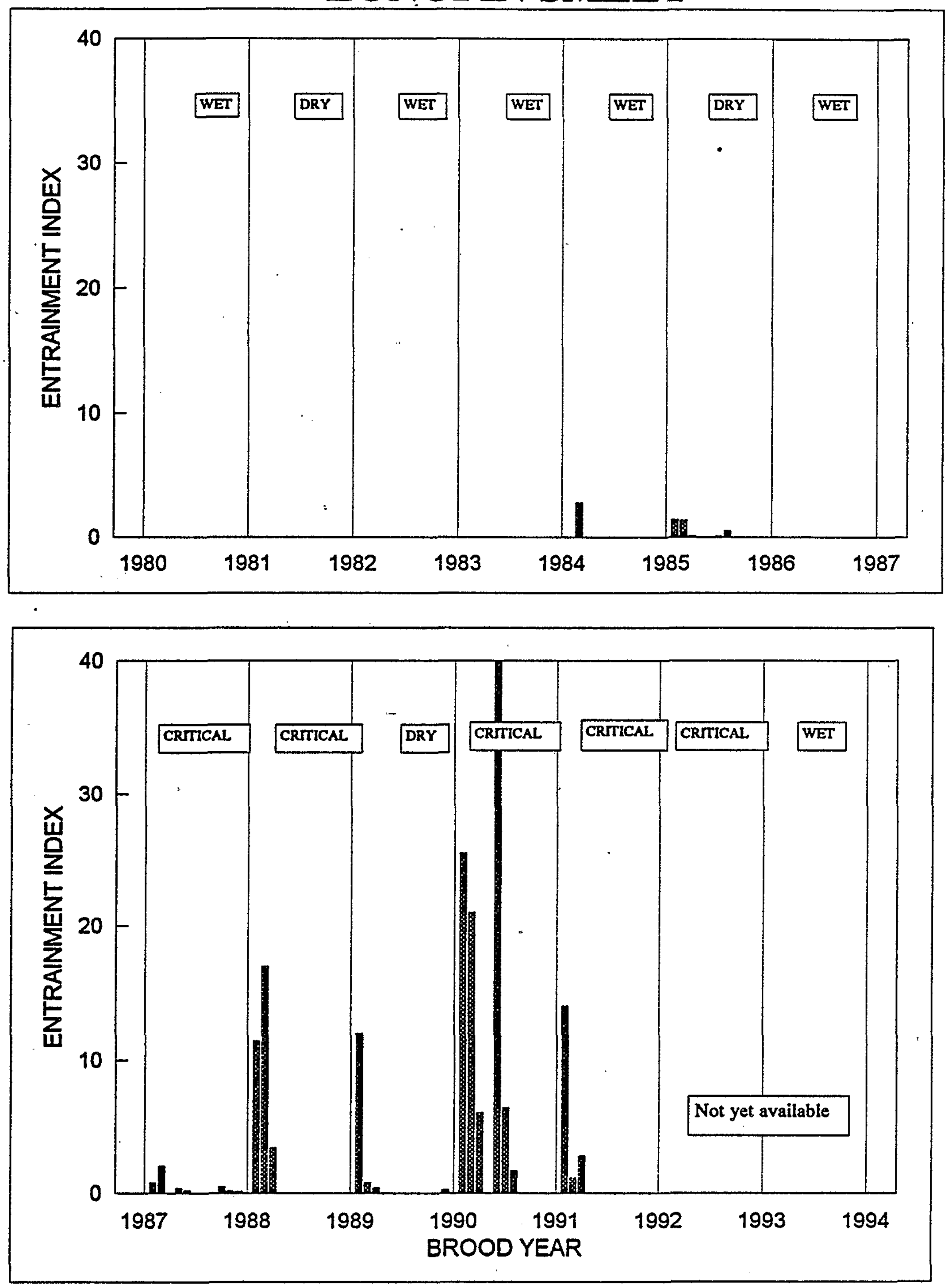


Figure 3.4 Entrainment indices (ratio of salvaged fish and subsequent abundance index) for CVP fish facilities. Exports at pumps tend to take a higher proportion of longfin smelt in dry years. Trends are similar at the SWP.

Longfin Smelt Recovery Criteria Stations

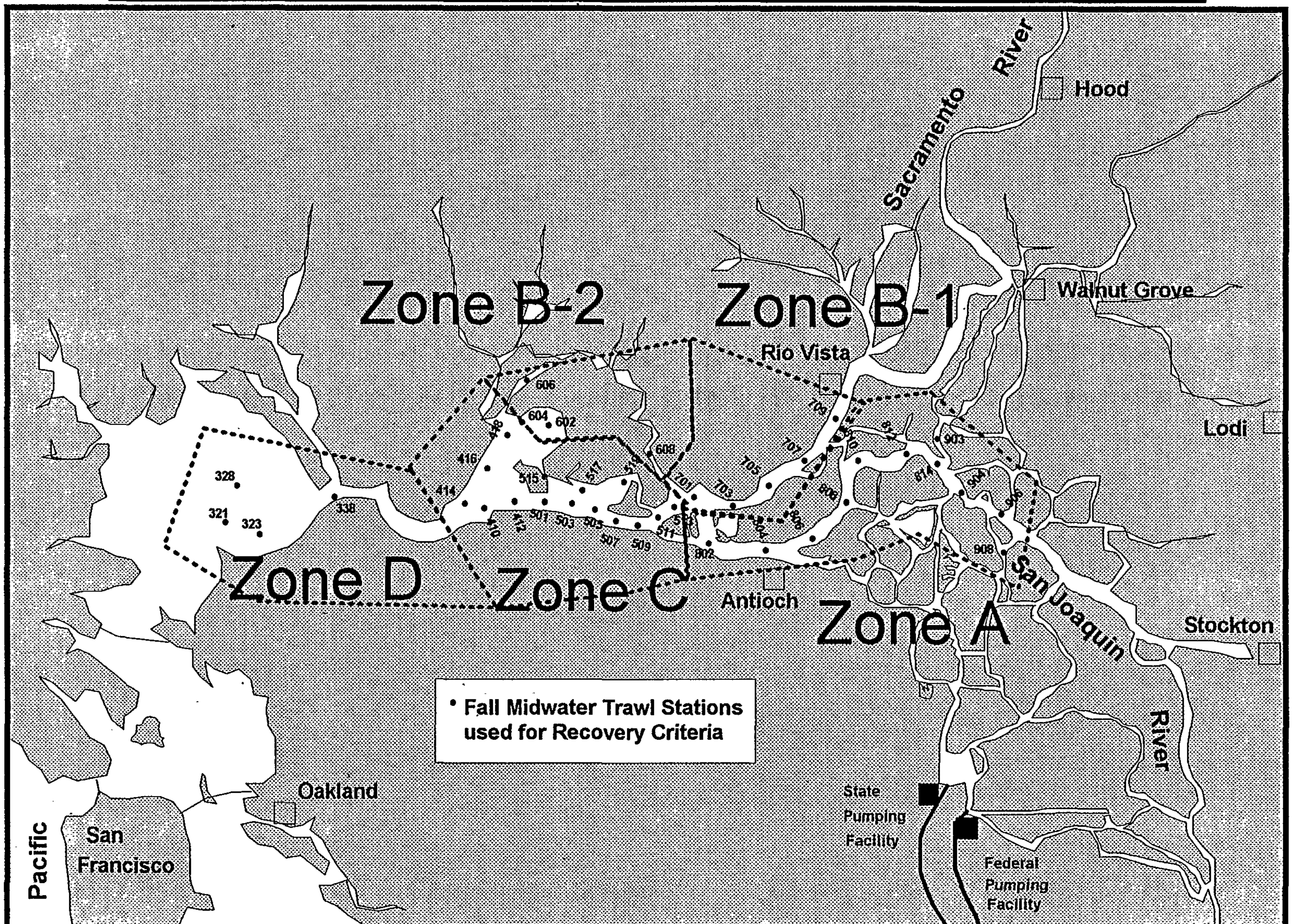


Figure 3.5 Longfin smelt recovery criteria stations.

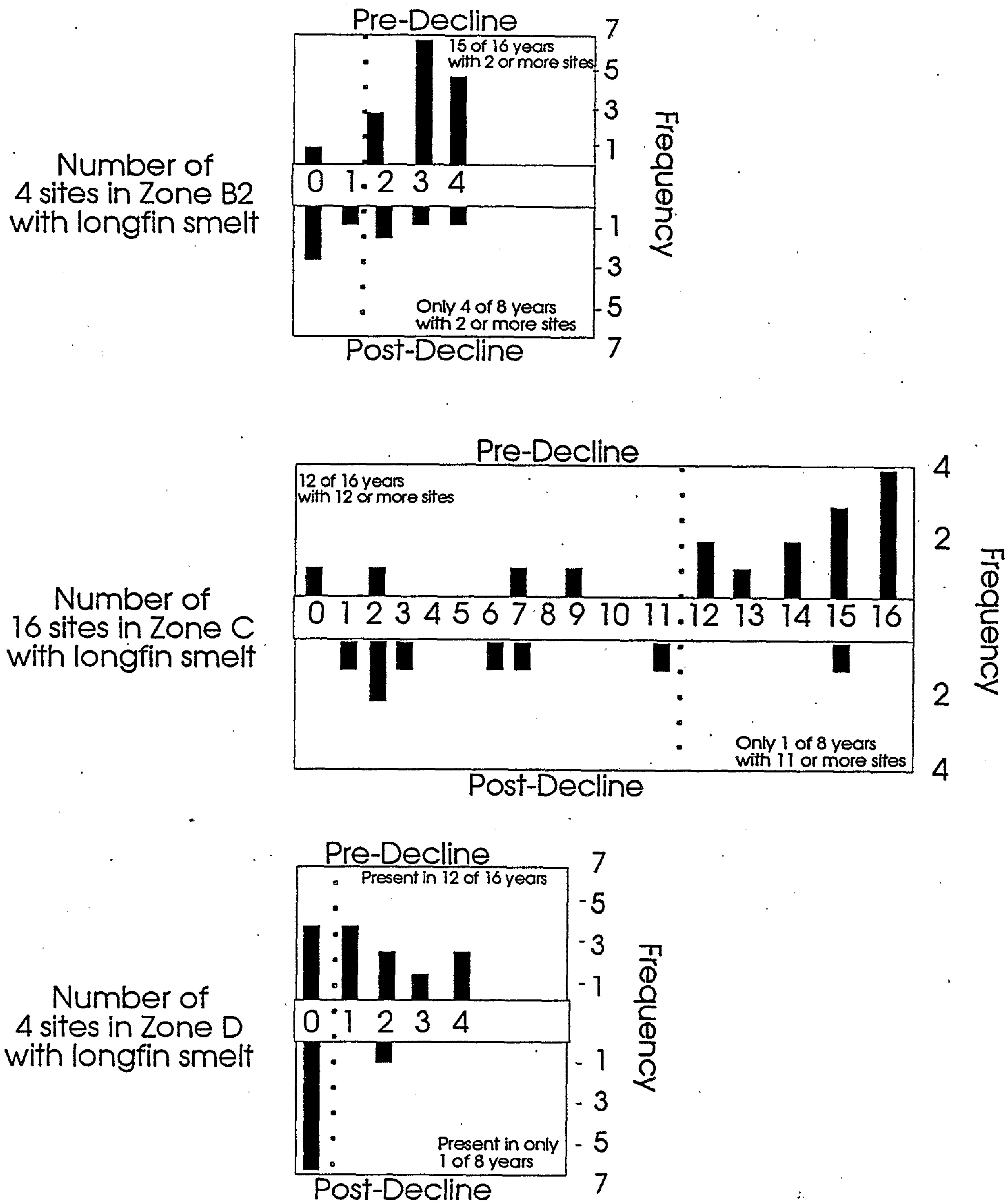


Figure 3.6 Nimber of sites with longfin smelt pre- and post-decline.

4. SACRAMENTO SPLITTAIL

Pogonichthys macrolepidotus (Ayres)

Introduction

Status: Endemic species. Proposed for listing as threatened, January 6, 1994.

Recovery potential: 7C. This rating is based on the fact the splittail is the only member of its genus (a second species is now extinct) and endemic to the Central Valley. Although its range and populations are greatly diminished, there seems to be only a moderate degree of threat of extinction in the near future because of its long life span and high fecundity. There is also a high potential for recovery.

Description: Splittail are large cyprinids, growing in excess of 300 mm SL, and are distinctive in having the upper lobe of the caudal fin larger than the lower lobe. The body shape is elongate with a blunt head. Small barbels may be present on either side of the subterminal mouth. They possess 14 to 18 gill rakers, and their pharyngeal teeth are hooked and have narrow grinding surfaces. Dorsal rays number from 9-10, pectoral rays 16-19, pelvic rays 8-9, and anal rays 7-9. The lateral line usually has 60-62 scales, but ranges from 57-64. The fish are silver on the sides and olive grey dorsally. Adults develop a nuchal hump. During the breeding season, the caudal, pectoral, and pelvic fins take on a red-orange hue and males develop small white nuptial tubercles in the head region.

Taxonomic Relationships: This species was first described in 1854 by W. O. Ayres as *Leuciscus macrolepidotus* and by S. F. Baird and C. Girard as *Pogonichthys inaeqilobus*. Ayres' species description is accepted as the official one but *Pogonichthys* was accepted as the genus name in recognition of its distinctive characteristics (Hopkirk 1973). The splittail is considered by some taxonomists to be allied to cyprinids of Asia (Howes 1984). The genus *Pogonichthys* comprises two species, *P. ciscoides* Hopkirk and *P. macrolepidotus* (Hopkirk 1973). The former species from Clear Lake, Lake County, became extinct in the early 1970s.

Distribution: The Sacramento splittail is a central California endemic that was once distributed in lakes and rivers throughout the Central Valley. They were found as far north as Redding by Rutter (1908) who collected them at the Battle Creek Fish Hatchery in Shasta County. Splittail are no longer found in this area and seem to be limited by the Red Bluff Diversion Dam in Tehama County to the downstream reaches of the Sacramento River. They also enter the lower reaches of the Feather River on occasion, but records indicate that Rutter (1908) had collected them as far upstream as Oroville. Splittail are also known from the American River and have been collected at the Highway 160 bridge in Sacramento, although in the past Rutter (1908) collected them as far upstream as Folsom. He also collected them from the Merced River at Livingston and from the San Joaquin River at Fort Miller (where Friant Dam is today). Snyder (1905) reported catches of splittail from southern San Francisco Bay and at the mouth of Coyote Creek in Santa Clara County, but recent surveys indicate that splittail are no longer present in these locations (Leidy 1984).

Splittail are now largely confined to the Delta, Suisun Bay, Suisun Marsh, Napa River, Petaluma River, and other parts of the Sacramento-San Joaquin estuary (Caywood 1974, Moyle 1976, Moyle, unpublished data). In the Delta, they are most abundant in the north and west portions, although other areas may be used for spawning (CDFG 1987a). This may reflect a shrinking of their Delta habitat because Turner and Kelley (1966) found a more even distribution throughout the Delta. Recent surveys of San Joaquin Valley streams found small numbers of splittail in the San Joaquin River below its confluence with the Merced River (Saiki 1984); large numbers of juveniles were caught in 1986 in the San Joaquin River 10-12 km above the junction with Tuolumne River (T. Ford, Turlock Irrigation District; personal communication). Successful spawning has been recorded in the lower Tuolumne River during wet years in the 1980s, with both adults and juveniles observed at Modesto, 11 km upriver from the river mouth (T. Ford, personal communication). Further surveys are needed to determine how far up the San Joaquin River splittail presently migrate for spawning, and if they spawn in the Merced River and other tributaries. Occasionally, splittail are caught in San Luis Reservoir (Caywood 1974) which stores water pumped from the Delta. Except when spawning, splittail are largely absent from the Sacramento River. Large individuals are caught during spring in the lower river in large fyke traps set to catch striped bass migrating upstream to spawn (CDFG, unpublished data). Presumably the splittail are also on a spawning migration. In the spring of 1993, adult and young-of-year splittail were captured in isolated pools in the Sutter and Yolo by-passes (W. Shaul, Jones and Stokes, Inc., personal communication) and a single individual was captured in Big Chico Creek, Butte Co., in 1993 (USFWS, unpublished data). Captures of larval fish indicate that an important spawning area for splittail may be the Sacramento River between the mouths of the American and Feather rivers (J. Wang, personal communication).

Habitat Requirements: Splittail are primarily freshwater fish, but are tolerant of moderate salinities and can live in water with salinities of 10-18 ppt (Moyle 1976, unpublished observation). In the 1950s, they were commonly caught by striped bass anglers in Suisun Bay during periods of rising tides (D. Stevens, CDFG, personal communication). During the past 20 years, however, they have been found mostly in slow-moving sections of rivers and in sloughs and have been most abundant in the Suisun Bay/Marsh region (Meng 1993). They are year around residents in Suisun Marsh, concentrating in the dead-end sloughs that typically have small streams feeding into them (Daniels and Moyle 1983; Moyle et al. 1986). They tend to be most abundant where other native fishes are abundant as well. In Suisun Marsh, trawl catches are highest in summer when salinities are 6-10 ppt and temperatures are 15-23° C (Moyle *et al.* 1986), reflecting in part the increased vulnerability of young-of-year fish to capture with increased size. In Suisun Bay, splittail of all sizes are most consistently found in shallow water at salinities less than 2-3 ppt (Meng 1993). In spring, both adult and young-of-year splittail are frequently found in shallow, flooded areas, such as the Yolo and Sutter by-passes, low-lying parts of delta islands (e.g., Miller Park), and river mouths.

Young-of-year and age-1 splittail were common in beach seine sampling by CDFG during 1993 along the Sacramento River between Rio Vista and Chipps Island (R. Baxter, CDFG, personal communication). Furthermore, in the CDFG Bay Study samples, splittail are more common from stations less than 6.7 m (21 ft) deep. Thus, juvenile splittail may be concentrated in the shallow peripheries of the Sacramento River, and they may be more abundant there than indicated by sampling done to date (R. Baxter, personal communication).

Daniels and Moyle (1983) found that year-class success in splittail was positively correlated with Delta outflow, and Caywood (1974) found that a successful year class was associated with winter runoff sufficiently high to flood the peripheral areas of the Delta. These observations were confirmed by the analysis of the State (CDFG 1992b). Meng (1993) found a strong negative relationship between amount of water diverted from the delta and abundance of young splittail, noting that the effect of diversions seemed to be particularly strong in dry years.

Life History: Splittail are relatively long-lived (about 5-7 years) and are highly fecund (up to 100,000 eggs per female). Their populations fluctuate on an annual basis depending on spawning success and strength of the year class (Daniels and Moyle 1983). Both male and female splittail mature by the end of their second year (Daniels and Moyle 1983), although occasionally males may mature by the end of their first year and females by the end of their third year (Caywood 1974). Fish are about 180-200 mm SL when they attain sexual maturity (Daniels and Moyle 1983), and the sex ratio among mature individuals is 1:1 (Caywood 1974).

There is some variability in the reproductive period, with older fish reproducing first, followed by younger fish which tend to reproduce later in the season (Caywood 1974). Generally, gonadal development is initiated by fall, with a concomitant decrease in somatic growth (Daniels and Moyle 1983). By April, ovaries reach peak maturity and account for approximately 18% of the body weight. The onset of spawning seems to be associated with increasing water temperature and day length and occurs between early March and May in the upper Delta (Caywood 1974). However, Wang (1986) found that in the tidal freshwater and euryhaline habitats of the Sacramento-San Joaquin estuary, spawning occurs by late January/early February and continues through July. Spawning times are also indicated by the salvage records from the State Water Project pumps. Adults are captured most frequently in January through April, when they are presumably engaged in spawning movements, while young-of-year are captured most abundantly in May through July (Meng 1993). These records indicate most spawning takes place from February through April.

Splittail spawn on submerged vegetation in flooded areas. Spawning occurs in the lower reaches of rivers (Caywood 1974), dead-end sloughs (Moyle 1976) and in the larger sloughs such as Montezuma Slough (Wang 1986). Larvae remain in the shallow, weedy areas inshore in close proximity to the spawning sites and move into the deeper offshore habitat as they mature (Wang 1986).

Strong year classes have been produced even when adult numbers are low, if outflow is high in early spring (e.g., 1982, 1986). Since 1988, recruitment has been consistently lower than expected, suggesting this relationship may be breaking down (Meng 1993). For example, both 1978 and 1993 were wet years following drought years, yet the young-of-year abundance in 1993 was only 2% of the abundance in 1978.

Splittail are benthic foragers that feed extensively on opossum shrimp (*Neomysis mercedis*) although detrital material typically makes up a high percentage of their stomach contents (Daniels and Moyle 1983). They will feed opportunistically on earthworms, clams, insect larvae, and other invertebrates. They are preyed upon by striped bass and other predatory fishes. The preference for splittail by striped bass has long been recognized by anglers, who fish for splittail to use them for bait.

Abundance: Splittail have disappeared from much of their native range because dams, diversions, and agricultural development have eliminated or drastically altered much of the lowland habitat these fish once occupied. Access to spawning areas or upstream habitats is now blocked by dams on the large rivers such as Nimbus Dam on the American River and Oroville Dam on the Feather River. Because splittail seem incapable of negotiating existing fishways, they cannot ascend the Sacramento River further than Red Bluff Diversion Dam. They are rare, however, more than 10-20 km above the upstream boundaries of the Delta. Caywood (1974) found a consensus among splittail anglers that the fishery had declined since the completion of Folsom and Oroville Dams. In the San Joaquin River, their distribution may be limited in good part by water quality (high temperature, pollutants) because they seem to move up into the river only during wet years.

Today the principal habitat of splittail is the Sacramento-San Joaquin estuary, especially the Delta. Their abundance in this system is strongly tied to outflows, presumably because spawning occurs over flooded vegetation. Thus, when outflows are high, reproductive success is high, but when outflows are low, reproduction tends to fail (Daniels and Moyle 1983). CDFG confirms this observation:

> "[S]uccessful reproduction is strongly associated with high outflows preceding, during and following spawning as demonstrated by high correlations between abundance of splittail in the fall

midwater trawl survey and various monthly combinations of Delta outflow from the previous winter through early summer." (CDFG 1992b, p. 2)

Even within their constricted range within the Delta, splittail populations are estimated to be only 35% to 60% as abundant as they were in 1940 (CDFG 1992b), and considered over their historic range, the percentage decline is much greater. Since 1980 splittail numbers in the Delta have declined steadily (Moyle *et al.* 1986), and in 1992 numbers declined to the lowest on record (P. Moyle and CDFG, unpublished data). Population levels appear to fluctuate widely from year to year; CDFG midwater trawl data for 1967-1990 indicate a decline from the mid-1960s to the late 1970s, a resurgence (with fluctuations) through the mid-1980s, and a decline since 1986. Survey data for Suisun Marsh (UCD, unpublished data) show a substantial decline in numbers during the period 1979-1991 (mean catch in 1979-1983, ca. 188 fish/month, mean catch in 1987-1990, ca. 25 fish/mo., 1990-1991, 3-5 fish/month). Data from the CDFG Bay-Delta survey and fish salvage operations at the State and Federal pumping plants in the south Delta indicate that splittail recruitment success is highly variable from year to year. Large pulses of young fish were observed in 1982, 1983 and 1986, but recruitment was low in 1980, 1984, 1985 and 1987-1990. Since 1985, splittail have been rare in San Pablo Bay, reflecting a constriction of their distribution to the upper Bay-Delta areas and to isolated areas like the Petaluma and Napa rivers.

Reasons for decline: Since the start of the massive influx of non-native peoples into California in the 1850s, the range and abundance of splittail has steadily declined. It is now largely confined to the Sacramento-San Joaquin estuary, except for occasional forays upstream to spawn. This means that its long-term survival depends upon conditions in the estuary and having adequate spawning habitat. The continuing decline in splittail numbers can be attributed to a variety of interacting factors, in approximate order of importance: (1) changed estuarine hydraulics, especially reduced outflows, (2) modification of spawning habitat, (3) climatic variation, (4) toxic substances, (5) introduced species, (6) predation, and (7) exploitation.

1. Changed estuarine hydraulics

For Sacramento splittail, the preeminent factor in their decline appears to have been habitat constriction associated with the reduction of water flows and changed hydraulics in the Sacramento-San Joaquin Delta. CDFG (1992b) indicates that such changes are probably the largest factor contributing to the decline of splittail because of the strong positive correlation between splittail year class success and outflows. The U.S. Bureau of Reclamation has acknowledged the adverse effects of the Delta export facilities on the estuarine fishes in its testimony to the State Water Resources Control Board in the interim water rights proceeding for the Bay-Delta estuary (1992):

> ". . . Reclamation believes the negative impact of Delta diversions on the fisheries and food chain is largely a consequence of the flow patterns (hydrodynamics) resulting from Delta inflow and CVP/SWP exports. Consequently, any proposed solution must address this important issue if it is to be effective in the long-term." (WRINT-USBR-Exhibit Number 10, p. 8.)

While the exact mechanism that reduces splittail recruitment during low outflow-high diversion years is not well understood, direct entrainment in the CVP and SWP pumps and shifting of splittail populations to the presumably less favorable conditions of the south Delta are possible contributors to low survival. During the period of decline, exceptionally high numbers of splittail have been salvaged from the pumping plants in some years (1986, 1993). In addition, since 1983 catches of splittail in the fall midwater trawl survey have become more frequent in the south Delta and the Sacramento River and less frequent in Suisun Bay (Meng 1993). Assuming this survey accurately reflects splittail distribution, this shift may indicate that young-of-year splittail have an increased probability of within delta entrainment, as well as being placed in conditions less favorable for growth and survival. However, there is a positive correlation between total splittail abundance in the CDFG fall midwater trawl survey and the number salvaged at the pumping plants ($r^2 = 0.46$, $P < 0.05$), indicating that splittail may be entrained in direct proportion to their abundance without proportionately higher salvage rates in dry years (Figure 4.1) (DWR/USBR 1994).

2. Modification of spawning habitat

While the spawning habitat of splittail has not been well characterized, the best evidence indicates that they spawn on flooded vegetation in the lower reaches of rivers and perhaps in the Delta and Suisun Marsh as well. It is probable that the early larval stages also live in the flooded vegetation, where rotifer and microcrustacean populations are likely to be high. The increase in flooded vegetation is presumably one of the factors contributing to splittail year class success in wet years. The decrease in riparian marshlands (floodable areas) in recent decades is consequently likely to be a major contributor to the general decline in splittail numbers.

3. Climatic fluctuations

The past 15 years have seen some of the most extreme environmental conditions the estuary has experienced since the arrival of Europeans. The years 1985-1992 were ones of continuous drought, broken only by the record outflows of February 1986. The prolonged drought had two major interacting effects: a natural decrease in outflow and an increase in the proportion of inflowing water being diverted. A natural decline in splittail numbers would be expected from the reduced outflow, presumably because of the reduced availability of spawning and larval rearing habitat. However, the increase in diversions has decreased survival of splittail through further reduction in habitat, especially in the lower Delta and Suisun Marsh. It is important to recognize that extreme floods and droughts have occurred in the past and splittail have managed to persist through them. However, the splittail historically did not experience the extreme conditions caused by increased diversion of water and by the shortage of potential spawning areas, nor did they have the reduced populations that make recovery from natural disasters much more difficult.

4. Toxic substances

The effects of pesticides and other toxic substances on splittail is not known, but there is considerable potential for negative interactions, especially when larvae are in the Sacramento River and Delta. This area needs investigation.

5. Introduced species

Introduced species are a perpetual problem in the Sacramento-San Joaquin estuary, especially those that are introduced "accidentally" from the ballast water of ships. The most recent problem introductions have been several species of planktonic copepods and an Asiatic clam, *Potamocorbula amurensis*. The copepods are regarded as a problem because they seem to be replacing *Eurytemora affinis*, a native copepod that has been the favored food of larval fish and of opossum shrimp, the favored prey of splittail. Although one of the introduced copepod species *(Sinocalanus doerrii)* seems to be harder for larval fish (and perhaps opossum shrimp, L. Meng, unpublished data) to capture, other introduced copepod species probably do not present the capture problems of *S. doerrii* (e.g., Meng and Orsi 1991). The Asiatic clam, in contrast, may have a direct effect on splittail populations because it has become extremely abundant in Suisun Bay, from which it appears to be filtering out much of the planktonic algae, the base of the food web that leads to splittail through opossum shrimp (Nichols *et al.* 1990). The splittail occurs in many areas where the clam is not abundant. The clam, however, is not a direct cause of the initial decline of splittail because it did not invade until after February 1986, when the estuary's biota had been devastated by immense outflows (Nichols *et al.* 1990). The clam's present abundance may make the recovery of splittail more difficult but it is quite likely that the Asiatic clam will become less abundant in response to increased freshwater outflows and to its discovery as a food source by fishes such as sturgeon, by invertebrates such as the invading green crab, and by diving ducks. A typical pattern for invading species is to have a population explosion in response to optimal conditions at the time of invasion (due to the absence of their predators, parasites, etc.) and then a decline to lower levels as the local ecosystem adjusts to their presence.

6. Predation

Splittail are preyed upon by introduced striped bass but they have successfully coexisted with striped bass since its introduction in the 1870s. Nevertheless, it is possible that increased predation by striped bass and other predators on splittail drawn into Clifton Court Forebay by the changed hydraulics of the Delta have been a contributing factor in their decline. In addition, the artificial enhancement of striped bass populations (which are also in decline) with hatchery fish (until 1992, when it was halted by CDFG) may have artificially increased predation rates on splittail. Large adult splittail are presumably largely immune to such predation.

7. Exploitation

Although splittail have been harvested as food and bait by sport anglers, there is no evidence that this exploitation has contributed to their decline. However, the Asian sport fishery in the past has concentrated on presumably spawning fish, so it could inhibit recovery of the species.

Conservation measures: Conservation measures discussed in the delta smelt section will also benefit splittail, although the unique spawning and habitat requirements of splittail mean that additional actions to enhance splittail populations will probably be necessary.

Research is currently underway by CDFG, DWR, Bureau of Reclamation, USFWS, UCD, and others to learn more about the life history and habitat requirements of splittail.

RECOVERY

Objective

The objective of this part of the Delta Native Fishes Recovery Plan is to protect Sacramento splittail, a species proposed for threatened status under the Federal Endangered Species Act. Recovery of splittail should not be at the expense of other Delta native fishes. Splittail will be considered out of danger when their population dynamics and distribution patterns within the estuary are similar to those that existed from 1967-1983. This period was chosen because it includes the earliest continuous data on splittail abundances and was a period when splittail populations stayed reasonably high in most years within the estuary.

Splittail are currently restricted to a fraction of their historic range. Because restoration of splittail to their former range outside the Delta is unreasonable (i.e., it would require removal of major dams), recovery of the species refers primarily to recovery of the reduced Delta population. Nevertheless, some actions that may help restore the species to a portion of its previous upstream range: 1) creation of meander belts along the Sacramento River by levee setbacks; 2) creation of floodable wetlands in the lower San Joaquin, Tuolumne, and Stanislaus rivers; 3) marsh restoration in the Delta and Suisun Marsh; 4) managing bypasses for fish; and 5) removal of upstream barriers to migration.

Recovery Criteria

Splittail will be considered recovered when they meet two out of three possible recovery criteria, developed from three independent surveys. The three possible criteria are: 1) FMWT trawl numbers must be 19 or greater for 7 of 15 years; 2) Suisun Marsh catch per trawl must be 3.8 or greater AND catch of young-of-year must exceed 3.1 per trawl for 3 of 15 years; and 3) Bay Study otter trawl numbers must be 18 or greater AND catch of young-of-year must exceed 14 for 3 out of 15 years. Within each survey, if target criteria are not met at least once in 5 consecutive years, the recovery period for the failed survey will be re-started. Criteria depend on data collected by three independent surveys, two conducted by CDFG (fall midwater trawl and Bay Study otter trawl) and one conducted by UCD (Suisun Marsh otter trawl). These studies were chosen because they sample most of the splittail range and contain the earliest continuous data on splittail abundance. When any two out of three criteria are reached, splittail will be recovered.

Justification for using numbers from three surveys: Recovery criteria were built around three surveys to increase flexibility in how criteria are met. Splittail catches tend to be low in the long-term data sets available on the estuary, so using two out three surveys to meet the criteria provides added protection for splittail as well as flexibility for managers. The Bay Study and Suisun Marsh sample downstream portions of splittail range, so meeting abundance criteria in either one of these surveys will ensure wide distribution for splittail in the estuary. Numbers were chosen rather than the index because there is a high correlation between numbers and the index (r^2 = 0.83 for the FMWT). Furthermore, using numbers reduces confusion due to the widely published indices for striped bass and delta smelt. Numbers are also consistent with the rest of the recovery plan for other species.

Justification for using 1967-1983 for the pre-decline period: Graphs from the surveys were used to establish pre- and post-decline periods for splittail. As is the case for other species, especially delta smelt, the decline in splittail numbers actually occurred over a multi-year period from 1981-1985. Further, because splittail live for 5-7 years, drops in abundance are dampened by the presence of several year classes.

Length of recovery and delisting period: Because all splittail mature by three years, 15 years were chosen as the recovery period. Fifteen years represent five generations of splittail. Recovery criteria specify that numbers can not fall below the recovery target for five consecutive years. This is to protect splittail from reproductive failure and is based on historic FMWT data. Splittail numbers were very low from 1969-1974 and contributed to subsequent low numbers. Because splittail live from 5-7 years, a strong year class within this period is essential to sustain the species.

Recovery criteria: Recovery criteria are grouped and numbered by survey. When any two out of three recovery goals are reached splittail will be considered recovered.

(1) <u>Fall midwater trawl</u>. The FMWT data set was filtered down to stations sampled in at least 3/4 of the years (6 of 24 years could be missed) in at least one month. Based on this reduced data set, average abundance of splittail from 1967-1992 was 19 based on the FMWT (Table 4.1). In years prior to 1984 splittail abundance exceeded this number in 7 out of 15 years. Since 1983 abundance has fallen below this value in 7 out of 9 years.

Splittail will be considered recovered when the FMWT exceeds 19 for 7 out of 15 years. If splittail fail to meet this recovery criterion for five consecutive years, the recovery period will start over.

(2) Suisun Marsh criteria. Splittail catch per trawl has declined steadily in Suisun Marsh since 1979 from a high of 20.3 in 1979 to less than 1 for each year since 1984 (Table 4.1, Figure 4.2). The average catch per trawl from 1979-1992 was 3.8. Splittail catches in Suisun Marsh were greater than this in all but one year of the pre-decline period (4 out of 5 years). Since 1984 catch per trawl has fallen below this value for all years except one. Suisun Marsh criteria are important to the recovery of splittail because shallow, unrip-rapped backwaters of the marsh are preferred habitat of splittail, indicated by high catches taken there (over 11,800 fish in 14 years). Splittail recruitment in the marsh has been poor since 1984. From 1980-1983, average abundance of splittail young was 3.1 per trawl (Figure 4.2). Splittail young abundance has fallen below that value in every year since 1984 except 1986 (Figure 4.2). Because splittail live for 5-7 years, a successful year class is necessary at least every five years to prevent extinction.

Splittail will be considered recovered when Suisun Marsh catch per trawl exceeds 3.8 for 7 out of 15 years AND when splittail young abundance exceeds 3.1 per trawl for at least 3 out of 15 years. Splittail young abundance can be used to make up total abundance (i.e., 3.1 young per trawl can be applied to meet the 3.8 target). If these target criteria (both young and overall) are not met for 5 consecutive years, the recovery period will begin again.

(3) Bay Study. The average number of splittail captured by Bay Study otter trawls from 1980-1992 is 18 (Table 4.1). In the pre-decline years this number was met half the time. After the decline, these numbers were met a third of the time. In wet years, which are highly correlated with strong splittail year classes, young-of-year make up more than half of the Bay Study's catches (Figure 4.3). Splittail young catch per unit effort must exceed 14 in at least 3 of 15 years.

Splittail will be considered recovered when Bay Study otter trawl numbers exceed 18 for 7 out of 15 years AND when splittail young numbers exceed 14 for 3 out of 15 years. Young-of-year numbers can be applied to meet overall criterion. If these targets (both young and overall) are not met for five consecutive years, the recovery period will be re-started.

Table 4.1 Splittail captured by the fall midwater trawl (FMWT), Suisun Marsh fish survey and Bay Study otter trawl. Numbers for Suisun Marsh are splittail per trawl.

Years	FMWT	Suisun Marsh	Bay Study
		Pre-decline	
1967	52	----	----
1968	24	----	----
1969	15	----	----
1970	7	----	----
1971	6	----	----
1972	10	----	----
1973	4	----	----
1974	NS	----	----
1975	5	----	----
1976	1	----	----
1977	0	----	----
1978	34	----	----
1979	NS	20.3	----
1980	14	7.6	7
1981	20	4.5	1
1982	51	4.4	23
1983	63	2.4	45
		Post-decline	
1984	16	1.3	34
1985	14	0.65	36
1986	50	4..2	23
1987	28	2	14
1988	8	0.77	13
1989	5	0.78	9
1990	9	0.43	3
1991	15	0.96	11
1992	3	0.27	11

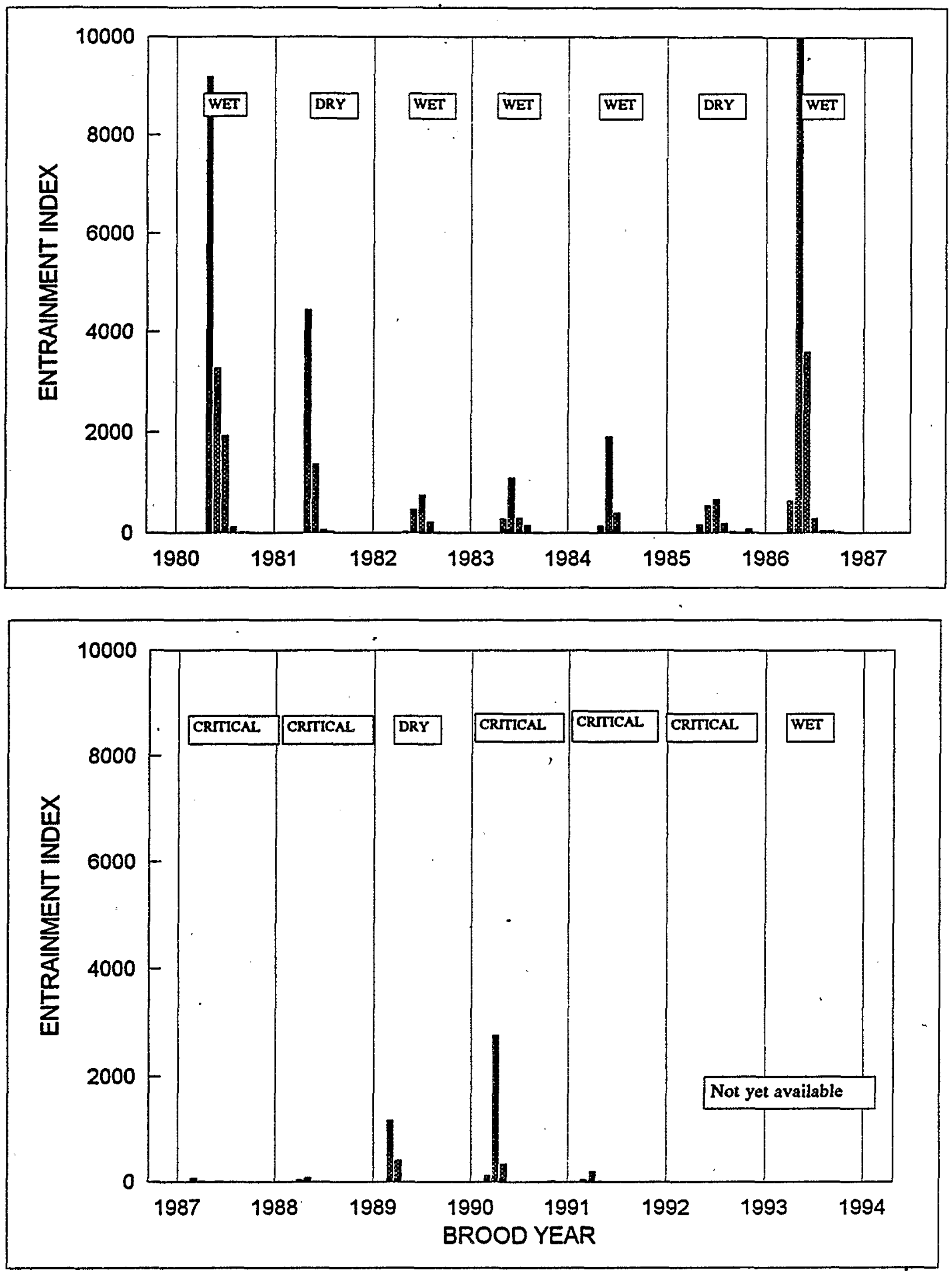


Figure 4.1 Entrainment indices (ratio of salvaged fish and subsequent abundance index) for CVP fish facilities. Exports at the pumps tend to take splittail in proportion to their abundance. Trends are similar at the SWP.

Splittail in Suisun Marsh

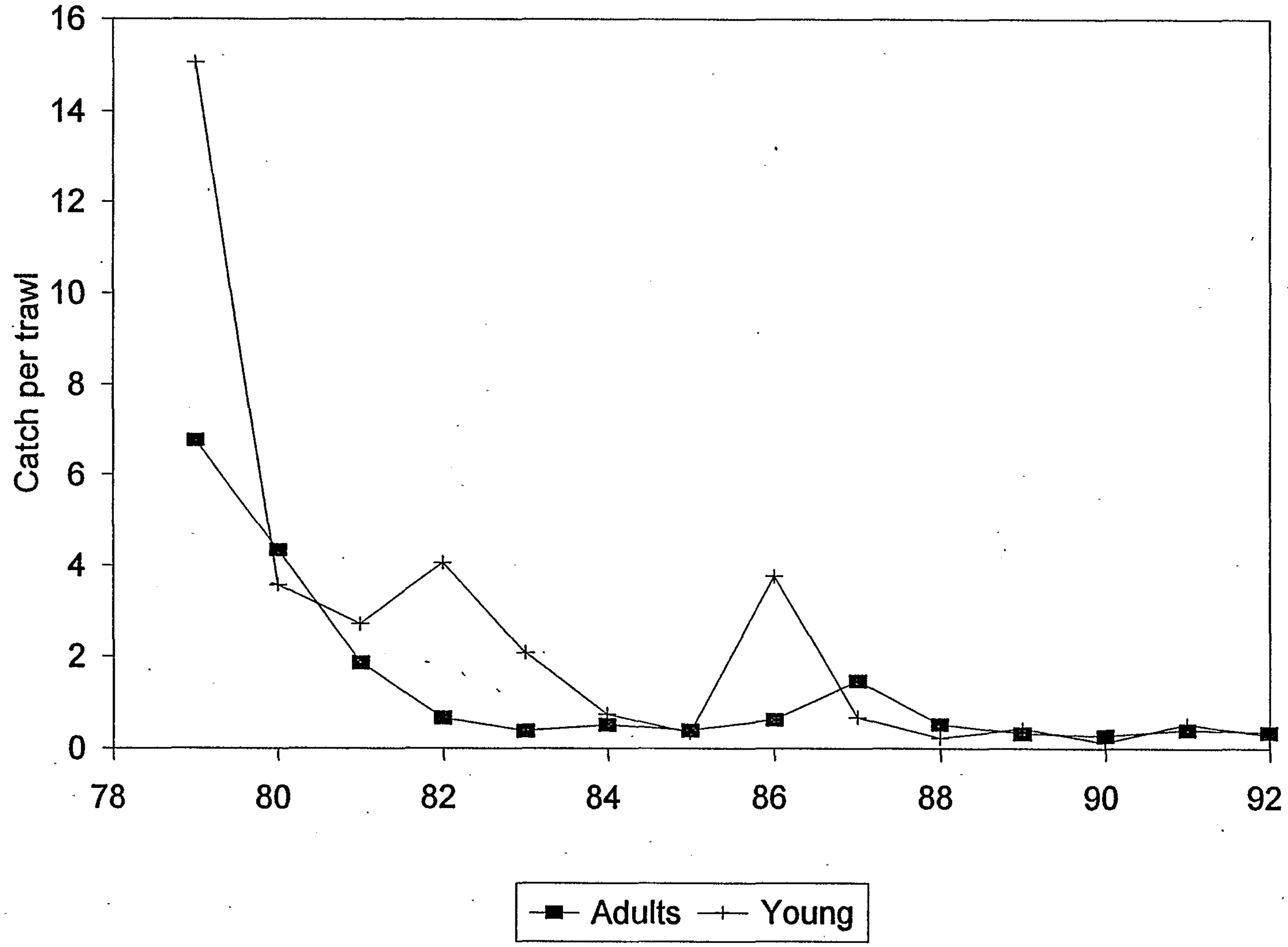


Figure 4.2 Abundance of splittail in Suisun Marsh.

C — 0 4 8 4 3 8

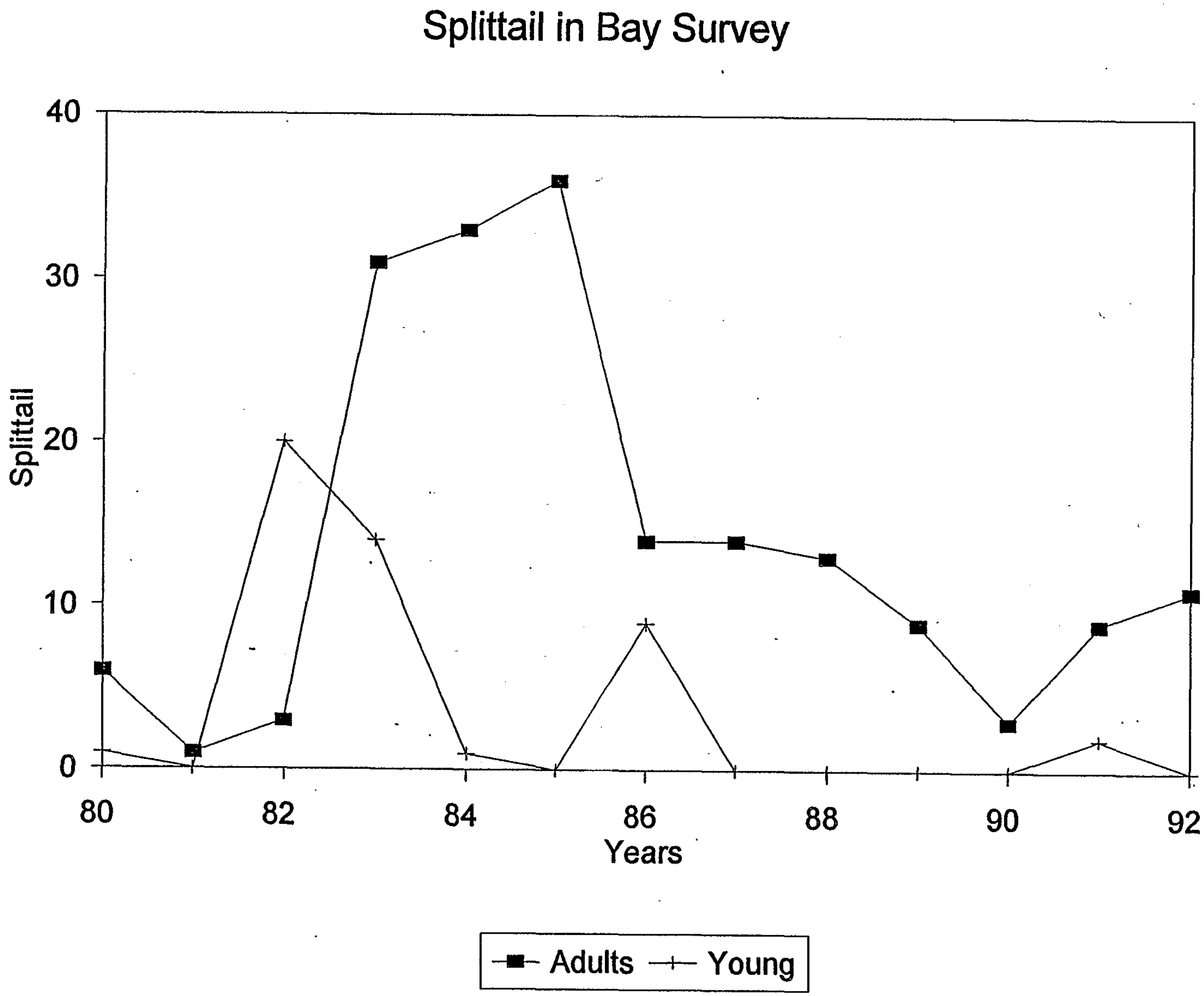


Figure 4.3 Abundance of splittail in Bay Survey.

5. GREEN STURGEON

Acipenser medirostris Ayres

Introduction

Status: The green sturgeon is a Category 2 candidate species. It is a legal sport fish in California, Oregon, and Washington and is commercially fished Oregon and Washington. It is considered a threatened species in Canada and Russia. Moyle *et al.* (1994) include them as a Species of Special Concern in California and recommend them for threatened species status.

Restoration potential: Moderate degree of threat, with high restoration potential.

Description: Sturgeons, with their large size, subterminal and barbeled mouths, lines of bony plates on the sides, and heterocercal (shark-like) tail, are among the most distinctive of freshwater fishes. Green sturgeon have a dorsal row of 8-11 bony plates (scutes), lateral rows of 23-30 scutes, and two bottom rows of 7-10 scutes. The dorsal fin has 33-36 rays, and the anal fin, 22-28. Green sturgeon are similar in appearance to white sturgeon (*Acipenser transmontanus*), with which they co-occur, except that the barbels are usually closer to the mouth than to the tip of the long, narrow snout. In addition, there is one large scute behind the dorsal fin, as well as behind the anal fin (both lacking in white sturgeon). Body color is olive-green, with an olivaceous stripe on each side and scutes that are paler than the body.

Taxonomic Relationships: The green sturgeon was described from San Francisco Bay in 1854 by W. O. Ayres as *Acipenser medirostris*, the only one of three species he described from the Bay that is still recognized. While there is no question about the validity of this species, geographic variation in the species has received little attention. It is likely that Asian populations belong to a different species or subspecies although they are morphologically similar to the North American populations and even share some unusual parasites (P. Foley, UCD, unpublished data). The Japanese population was described as *Acipenser mikadoi* based on one poorly preserved specimen (Jordan and Snyder 1906). Schmidt (1950) designated the Asian form (the Sakhalin sturgeon in Russian literature) as a distinct subspecies, *Acipenser medirostris mikadoi*. Recent DNA measurements indicate that the Asian form has approximately twice the DNA content of the North American form (Birstein 1993). Birstein (1993) thus considers them to be two separate species, the Asian form *A. mikadoi* Hilgendorf and the North American *A. medirostris*.

Distribution: In North America, the green sturgeon ranges in the ocean from the Bering Sea to Ensenada, Mexico, a range which includes the entire coast of California. They have been found in rivers from British Columbia south to the Sacramento River in California. There is no evidence of green sturgeon spawning in Canada or Alaska, although small numbers have been caught in the Fraser and Skeena rivers, British Columbia (Houston 1988). Green sturgeon are particularly abundant in the Columbia River estuary and individuals had been observed 225 km inland in the Columbia River (Wydoski and Whitney 1979); presently they are found almost exclusively in the lower 60 km and do not occur upstream of Bonneville Dam (Oregon Dept. Fish and Wildlife 1991). There is no evidence of spawning in the Columbia River or other rivers in Washington. In Oregon, juvenile green sturgeon have been found in several of the coastal rivers (Emmett *et al.* 1991) but spawning has only been confirmed in the Rogue River (A. Smith, minutes to USFWS meeting on green sturgeon, Arcata, California, May 3, 1990; P. Foley, unpublished notes). In California, green sturgeon spawning has been confirmed in recent years only in the Sacramento River and the Klamath River, although spawning probably once occurred in the Eel River as well (Moyle *et al.* 1993). More details on distribution are provided in the abundance section.

Habitat Requirements: Habitat requirements of green sturgeon are poorly known, but spawning and larval ecology probably are similar to that of white sturgeon. However, comparatively large egg size, thin chorionic layer on the egg, and other characteristics indicate that green sturgeon probably require colder, cleaner water for spawning than white sturgeon (S. Doroshov, UCD, personal communication). In the Sacramento River, adult sturgeon are in the river, presumably spawning, when temperatures range between 8-14°C. Preferred spawning substrate likely is large cobble, but can range from clean sand to bedrock. Eggs are broadcast-spawned and externally fertilized in relatively high water velocities and probably at depths >3 m (Emmett *et al.* 1991). The importance of water quality is uncertain, but silt is known to prevent eggs from adhering to each other (C. Tracy, minutes to USFWS meeting).

Life History: The ecology and life history of green sturgeon have received comparatively little study, evidently because of their generally low abundance and their low commercial and sport-fishing value in the past. The adults are more marine than white sturgeon, spending limited time in estuaries or fresh water.

Green sturgeon migrate up the Klamath River between late February and late July. The spawning period is March-July, with a peak from mid-April to mid-June (Emmett *et al.* 1991). Spawning times in the Sacramento River are probably similar, based on times when adult sturgeon have been caught there (see abundance section, below). Spawning takes place in deep, fast water. In the Klamath River, a pool known as "The Sturgeon Hole" (1.5 km upstream from Orleans, Humboldt County) apparently is a major spawning site, because leaping and other behavior indicative of courtship and spawning are often observed there during spring and early summer (Moyle 1976). Female green sturgeon produce 60,000-140,000 eggs (Moyle 1976), which are about 3.8 mm in diameter (C. Tracy, minutes to USFWS meeting). Based on their presumed similarity to white sturgeon, green sturgeon eggs probably hatch around 196 hours (at 12.7°C) after spawning, and larvae should be 8-19 mm long; juveniles likely range in size from 2.0 to 150 cm (Emmett *et al.* 1991). Juveniles migrate out to sea before 2 years of age, primarily during summer-fall (Emmett *et al.* 1991). Length-frequency analyses of sturgeon caught in the Klamath Estuary by beach seine indicate that most green sturgeon leave the system at lengths of 30-70 cm, when they are 1 to 4 years old, although a majority leave as yearlings (USFWS 1982). They remain near estuaries at first, but can migrate considerable distances as they grow larger (Emmett *et al.* 1991). Individuals tagged by CDFG in San Pablo Bay (part of the San Francisco Bay system) have been recaptured off Santa Cruz, California, in Winchester Bay on the southern Oregon coast, at the mouth of the Columbia River and in Gray's Harbor, Washington (Chadwick 1959; Miller 1972). Most tags for green sturgeon tagged in the San Francisco Bay system have been returned from outside that estuary (D. Kohlhorst, CDFG, personal communication).

Green sturgeon grow approximately 7 cm per year until they reach maturity at 130-140 cm, around age 15-20 (USFWS 1982). Thereafter growth slows down and maximum size in the Klamath River in recent years has been around 230 cm (USFWS 1982). The largest fish have been aged at 40 years, but this is probably an underestimate (T. Kisanuki, USFWS, personal communication). The largest green sturgeon are typically females and virtually all fish over 200 cm are female (USFWS 1982).

Juveniles and adults are benthic feeders and may also take small fish. Juveniles in the Sacramento-San Joaquin Delta feed on opossum shrimp (*Neomysis mercedis*) and amphipods (*Corophium* sp.) (Radtke 1966). Adult sturgeon caught in Washington had been feeding mainly on sand lances (*Ammodytes hexapterus*) and callianassid shrimp (P. Foley, unpublished data). In the Columbia River estuary, green sturgeon are known to feed on anchovies, and they perhaps also feed on clams (C. Tracy, minutes to USFWS meeting). Adults can reach sizes of 2.3 m FL and 159 kg, but in San Francisco Bay most are probably less than 45 kg (Skinner 1962).

Abundance: In California, green sturgeon have been collected in small numbers in marine waters from the Mexican border to the Oregon border. They have been noted in a number of rivers, but spawning populations are known only in the Sacramento and Klamath rivers (see below). The following distributional information on green sturgeon in California waters was provided by Mr. Patrick Foley (UCD).

Southern California. A small number of green sturgeon have been reported from the southern California coast (Fitch and Lavenberg 1971). The majority of these fish were less than 100 cm total length (TL) and weighed under 4 kg. The largest green sturgeon reported taken in the ocean south of Point Conception was a mature male, 163 cm and 25.7 kg, caught by a commercial fisherman near Dana Point, Orange County (Fitch and Schultz 1978).

Abundance of green sturgeon gradually increases northward of Point Conception. They are occasionally caught in Monterey Bay (G. Cailliet, California State University and R. Lea, CDFG, personal communication). A tagged green sturgeon was recovered near Santa Cruz, Santa Cruz County (Miller 1972). Within the holdings of the California Academy of Sciences (CAS) is a skeleton collected at Moss Landing Beach, Monterey County, and a complete specimen acquired from the Santa Cruz Municipal Pier Aquarium (D. Catania, CAS, personal communication).

Sacramento-San Joaquin drainage. The San Francisco Bay system, comprising San Francisco Bay, San Pablo Bay, Suisun Bay and the Delta, is home to the southernmost reproducing population of green sturgeon. In fact, green sturgeon were originally described from San Francisco (Ayres 1854). White sturgeon are the most abundant sturgeon in this system and green sturgeon have always been comparatively uncommon (Ayres 1854, Jordan and Gilbert 1883). Intermittent studies by CDFG between 1954 and 1991 have measured and identified 15,901 sturgeon of both species. Based on these data, a green sturgeon to white sturgeon ratio of 1:9 was derived for fish less than 101 cm fork length (FL) and 1:76 for fish greater than 101 cm FL (D. Kohlhorst, personal communication). If it is assumed that green sturgeon and white sturgeon are equally vulnerable to capture by various gear and that the CDFG population estimates of white sturgeon (11,000-128,000, depending on the year) are accurate (Kohlhorst *et al.* 1991), then the number of green sturgeon in the estuary longer than 102 cm has ranged from 200 to 1,800 fish (D. Kohlhorst, personal communication). These numbers should be regarded as very rough estimates because the above assumptions are uncertain.

Numbers of juvenile green sturgeon are presumably even more variable than number of adults since reproduction is presumably episodic (characteristic also of white sturgeon, Kohlhorst *et al.* 1991). One indication of this is the numbers of green sturgeon salvaged at the pumps of the SWP and CVP in the south Delta, which are mainly juveniles. Between 1979 and 1991, 6341 fish identified as green sturgeon were captured at the two facilities combined; 32,708 white sturgeon were identified in the same period. Annual numbers ranged from 45 (1991) to 1476 (1983). Other high salvage years were 1982 (1093) and 1985 (1377). However, these data are not particularly reliable because of poor quality control on both counts and species identification (D. Kohlhorst, personal communication). In addition, juvenile sturgeon are probably more vulnerable to entrainment at low or intermediate outflows.

Indirect evidence indicates that green sturgeon spawn mainly in the Sacramento River. They have been reported in the mainstem Sacramento River as far north as Red Bluff, Tehama County (river km 383) (Fry 1979). Small, young green sturgeon have been taken near Hamilton City, Glenn County (river km 317)(Fry 1979). Additionally, four young green sturgeon were collected at the Red Bluff Diversion Dam in late October, 1991 (K. Brown, USFWS, personal communication). River guides have taken adult green sturgeon at the Anderson Hole, about 6 km above the Hamilton Bridge (G. Jewell, personal communication). A dead adult green sturgeon was found on April 18, 1991, at river km 378 (approximately 5 kilometers south of Dairyville, Tehama County), by biologists from (USFWS) (K. Brown, personal communication). Live adult green sturgeon have been observed by USFWS crews surveying winter-run chinook salmon, *Oncorhynchus tshawytscha*, in the 16-km reach of river below Red Bluff Diversion Dam in 1991 and 1992 (K. Brown, personal communication). In 1991, 20 large sturgeon were sighted in this area between April 3 and May 21. Pat Foley of UCD reported recent photographs of green sturgeon taken by sportfishers in the Feather River, a tributary of the Sacramento. It is possible that some spawning may take place in the San Joaquin River, because young green sturgeon have been taken at Santa Clara Shoal, Brannan Island State Recreational Area, Sacramento County (Radtke 1966) and a single specimen from Old River is in the California Academy of Science collection (D. Catania, CAS, personal communication).

North Coast. North of San Francisco, green sturgeon are encountered with greater frequency. They are recorded from Tomales Bay (Blunt 1980, D. Catania, personal communication) and, while numbers are small, they are roughly equal in abundance to white sturgeon (Richard Plant, personal communication). A green sturgeon tagged in San Francisco Bay was recovered near Bodega Head (D. Kohlhorst, personal communication) and small numbers are taken incidentally by a near-shore halibut fishery centered at Bodega Bay (C. Haugen, personal communication). Further north, a single specimen was collected from the Noyo River (D. Catania, personal communication).

From the Eel River northward, green sturgeon predominate in rivers and estuaries along the coast of California, and it is likely that most records of sturgeon caught in rivers between San Francisco Bay and the Klamath River refer to green sturgeon. However, most early references regarding sturgeon from this area failed to identify the species and some reports indicated white sturgeon to be more abundant (Fry 1979). As a result, much confusion has ensued as to the relative abundance of both species throughout this region. Historical accounts from 19th century newspapers (The Humboldt Times) provide the earliest evidence of sturgeon in the Eel River drainage. At this time sturgeon were reported from the mainstem Eel River, South Fork of Eel River and the Van Duzen River (Wainwright 1965). While not confirmatory, length and weights given in these newspaper accounts would be consistent with adult green sturgeon.

In the middle part of this century, two young green sturgeon were collected in the mainstem Eel River and large sturgeon were observed jumping in tidewater (Murphy and DeWitt 1951). Two additional young green sturgeon were taken from the Eel River in 1967 and are in the fish collection at Humboldt State University. Substantial numbers of juveniles were caught by CDFG in the mainstem Eel River during trapping operations in 1967-1970 (O'Brien *et al.* 1976): 22 at Eel Rock in 1967, 53 at McCann in 1967 and 161 in 1969, 221 at Fort Seward in 1968, and smaller numbers at other localities. Green sturgeon have been included in lists of natural resources found in the Eel River estuary (Monroe and Reynolds 1974, Blunt 1980) but there have been no confirmed records of green sturgeon in the Eel River since 1970. Recent (1993) reports from CDFG personnel indicate that at least some sturgeon-- most likely green sturgeon-- still occur there (P. Foley, personal communication). It is not known, however, if they are spawning in the Eel River.

Records of sturgeon in the Humboldt Bay system, comprising Arcata Bay to the north and Humboldt Bay to the south, are almost exclusively green sturgeon. Ten years of trawl investigations in South Humboldt Bay produced three green sturgeon (Samuelson 1973). Records from Arcata Bay are more numerous. On August 6 and 7, 1956, 50 green sturgeon were tagged in Arcata Bay by CDFG biologist Ed Best (D. Kohlhorst, personal communication). Total lengths ranged from 57.2 cm to 148.6 cm with a mean TL of 87.0 cm ($\pm$ 20.6 cm SD). In 1974, nine green sturgeon were collected over a two-month period in Arcata Bay (Sopher 1974). Total length of these fish ranged between 73-112 cm.

The Coast Oyster Company, Eureka, pulls an annual series of trawls in Arcata Bay to decrease the abundance of bat rays, *Myliobatis californica*. Green sturgeon are incidentally taken in this operation. Eight green sturgeon collected for parasite evaluation in 1988 and 1989 had total lengths ranging between 78-114 cm. One large individual, 178 cm TL and 18.2 kg, was returned to the bay. Green sturgeon have been reported from the Mad River (Fry 1979). Recent evidence of their presence is lacking and any green sturgeon in the Mad River, due to the river's small size, would likely be limited to the estuary.

An occasional green sturgeon is encountered in the coastal lagoons of Humboldt County (T. Roelofs, Humboldt State University, personal communication). Big Lagoon and Stone Lagoon are connected to the ocean during part of the year and migrating sturgeon may gain entry at this time. In June 1991, a 120-cm green sturgeon was gillnetted in Stone Lagoon (T. Roelofs, personal communication).

Klamath and Trinity Rivers. The largest spawning population of green sturgeon in California is in the Klamath River Basin. Both green sturgeon and white sturgeon are found in the Klamath River estuary (Snyder 1908, USFWS 1980-91) but white sturgeon are taken infrequently, in very low numbers, and are presumed to be coastal migrants (USFWS 1982). A sturgeon investigation program initiated in 1979 by USFWS found that almost all sturgeon occurring above the estuary were green sturgeon (USFWS 1980-83). The sturgeon primarily use the mainstem Klamath River and mainstem Trinity River, but have also been seen in the lower portion of the Salmon River.

Both adults and juveniles have been identified in the mainstem Klamath River. Adults are taken annually, spring and summer, by an in-river Native American gillnet fishery. The numbers average around 500 fish per year (see below). They have also been taken by sport fishermen as far inland as Happy Camp (river km 172) (unpublished CDFG Tagging Data 1969-73, Fry 1979, USFWS 1981). However, the usual upstream limit for the spawning migration appears to be Ishi Pishi Falls, upriver from Somes Bar, Siskiyou County (approximately river km 113). A few juveniles have been taken as high up as Big Bar (river km 81) (T. Kisanuki, personal communication), but most have been recovered by seining operations directed at salmonids in the tidewater (USFWS, CDFG). Sampling by USFWS captured 7 juveniles in June 1991 and 23 in June-July 1992 (T. Kisanuki, personal communication).

The Trinity River enters the Klamath River at Weitchpec (river km 70). The earliest green sturgeon described from the Klamath Basin came from the Trinity River (Gilbert 1897). Both adults and juveniles have been identified; 211 sturgeon, between 7-29 cm TL, were captured near Willow Creek, Humboldt County, incidental to a salmonid migration study in July-September, 1968 (Healey 1970). The USFWS has collected juvenile green sturgeon in recent years from the Trinity River: 2 (in 1989), 0 (1990), 6 (1991) and 36 (1992) (T. Kisanuki, personal communication). Adults are caught yearly in a Native American gillnet fishery (USFWS 1980); based on the oral history as recounted by Yurok tribal elders, the Native American fishery has harvested green sturgeon since "historical" times-- at least since the turn of the 20th century, and quite likely earlier (T. Kisanuki, personal communication). Spawning migrants penetrate the mainstem Trinity River up to about Grays Falls, Burnt Ranch, Trinity County (river km 72).

Sturgeon have also been reported to use the South Fork Trinity River, a third-order stream entering above Willow Creek (river km 51) (USFWS 1981). Oral histories from old-time residents confirm this. However, a large flood in 1964 had devastating effects on anadromous fish habitat in this subbasin (U.S. Department of the Interior 1985). Millions of cubic yards of soil were moved into South Fork Trinity River and its tributaries. Channel widening and loss of depth resulted. This event, along with other changes in subbasin morphology, has apparently resulted in loss of suitable sturgeon habitat. There are no recent sightings from this watershed.

The Salmon River is a tributary to the Klamath River, entering at Somes Bar (river km 106). Its water is generally clear and becomes turbid only during high run-off periods. Adult sturgeon have been seen swimming up this river by observers standing on bluffs overhead. The approximate limit to the migration is at the mouth of Wooley Creek, 8 km upstream. Juveniles have yet to be found in the Salmon River, however.

Del Norte County. Green sturgeon have been taken during gillnet sampling in Lake Earl (D. McCloud, CDFG, personal communication). Lake Earl is located along the coast of Del Norte County, 8 km north of Crescent City and 11 km south of the mouth of Smith River. It is connected by a narrow channel to Lake Talawa, a smaller lake directly to the west. A sand spit separates Lake Talawa from the ocean and is occasionally breached by winter storms or by human activities. Coastal migrant green sturgeon enter at this time and become trapped after the sand spit is rebuilt (Monroe *et al.* 1975).

The Smith River is the northernmost river along the California coast, entering the ocean approximately 5 km south of the Oregon border. Blunt (1980) included green sturgeon in an inventory of anadromous species found in the Smith River. They occasionally enter the estuary and have been observed in Patrick's Creek, an upstream tributary 53 km from the ocean (Monroe *et al.* 1975). Juveniles have not been found.

Reasons for decline: The green sturgeon is apparently reduced in numbers throughout its range, although evidence is limited. In the Sacramento River, there is no direct evidence of a decline, but the population is quite small, so a collapse could occur under some conditions and yet hardly be noticed because of limited sampling. The reasons for considering the green sturgeon to be a potentially threatened species throughout its range are as follows:

(1) The green sturgeon is potentially in trouble throughout its range. Rochard *et al.* (1990) state in their review of the status of sturgeons worldwide: "Those [species of sturgeon] which do not have particular interest to fishermen (*A. medirostris, Pseudoscaphirhynchus* spp.) are paradoxically most at risk, for we know so little about them (p. 131)." In Japan, Asian green sturgeon have apparently been extinct for 40 or more years (K. Amaoka, personal communication); they once had spawning runs in the rivers of Hokkaido (Otaki 1907). In Russia, the Asian green sturgeon is listed as a Category 4 species (probably endangered but with insufficient information to be classified as such). Borodin *et al.* (1984) note that is has been little studied but "appears to be in great danger of extinction." Fishing for green sturgeon is now officially forbidden in Russia. In Canada, green sturgeon have been given "rare" status (1987) by the Committee on the Status of Endangered Wildlife in Canada (Houston 1988). They are considered to be a species of special concern in California by Moyle *et al.* (1994).

(2) A number of presumed spawning populations have apparently been lost in the last 25-30 years in California (e.g., South Fork Trinity River, Eel River) and the only known spawning populations are in the Sacramento, Klamath, and Rogue rivers, all of which have flow regimes affected by water projects. It is highly probable that these are now the only spawning populations in North America.

(3) The size and structure of their eggs indicate that green sturgeon are adapted for spawning in cold, low-silt water (S. Doroshov, personal communication), conditions that probably once existed most consistently in the Sacramento and other rivers above where Shasta Dam is now located. Because Red Bluff Diversion Dam has apparently been a barrier to green sturgeon migration until recently, it is possible that they have been forced to spawn in suboptimal conditions in the lower Sacramento River.

(4) The exploitation of green sturgeon in commercial, sport, Native American, and illegal fisheries appeared to have been excessive for many years. It likely that all these fisheries depend largely on

sturgeon from California. Compilation of data from various fisheries indicate that about 6,000 to 11,000 green sturgeon were being harvested per year. While there is no direct evidence of a decline, the statistics are very incomplete and it highly likely that fishing pressure has been increasing in recent years. In addition, the average size of the sturgeon being caught declined in the Columbia. This problem is less than it once was because of the 1993 ban on the sport fishery for sturgeon along the north coast, the elimination of the targeted commercial fishery in Washington, and the increase in minimum size for sturgeon in the California sport fishery.

In the Sacramento drainage, the major factors likely to be negatively affecting green sturgeon abundance are (1) fisheries, (2) modification of spawning habitat, (3) entrainment, and (4) toxic substances.

1. Fisheries

Sturgeon fisheries were "mining" a stock of large, old fish that was probably not able renew itself at annual harvest rates of 8 - 12%. Fisheries that affected green sturgeon occur both within and outside the Sacramento-San Joaquin estuary although recent changes in fishing regulations have reduced commercial and sport fisheries. The following are accounts of the local fishery and the two principal "outside" fisheries for green sturgeon.

Sacramento-San Joaquin fisheries. Green sturgeon in this drainage are caught primarily by sport anglers who are fishing for white sturgeon. If it is assumed that green sturgeon > 102 cm (official legal size prior to 1990) were harvested in proportion to their numbers relative to white sturgeon and at the same rate, then exploitation rates had been gradually increasing since 1954 (Kohlhorst *et al.* 1991). Kohlhorst et al. (1991) recommended several management options to reduce fishery mortality of white sturgeon; the action actually taken has been to increase the minimum harvest size to 46 inches (117 cm) in 2-inch (5 cm) increments and to impose a 72-inch (183 cm) maximum size limit (D. Kohlhorst, personal communication). These size limits also allow more white sturgeon females to mature, because they mature at a larger size than males. These regulations also apply to green sturgeon but are less protective of them because a majority of the largest and oldest individuals fall within the permitted size range.

Columbia River Region fisheries. The majority of green sturgeon harvest occurs in this region; they are caught by commercial fishermen, anglers, and Native American gillnetters. Sturgeon landings are recorded from the Columbia River estuary and from Grays Harbor and Willapa Bay, Washington, to the immediate north of the estuary. There is little or no evidence of green sturgeon spawning in rivers of this region, and it is likely that fish harvested here migrated from California or Oregon, as indicated by limited recaptures of tagged sturgeon. Further evidence of lack of local recruitment into the fishery is that few juvenile sturgeon (< 1.3 m) are caught (Emmett *et al.* 1991).

The commercial catch in the Columbia River region (Columbia River estuary, Grays Harbor, Willapa Bay) has fluctuated considerably, but catches seem to have increased in recent years. Between 1941 and 1951, catches averaged about 200-500 fish per year, while between 1951 and 1971 catch averaged about 1,400 fish per year (Houston 1988). In recent years an average of 4.7 tons of green sturgeon (ca. 300 - 500 fish) have been harvested each year in Grays Harbor and 15.9 tons (ca. 1,000-1,500 fish) are harvested in Willapa Bay (Emmett *et al.* 1991). There have also been some notably high catches; in 1986, 6,000 green sturgeon were harvested in the Columbia River estuary (Oregon Department of Fish and Wildlife (ODFW 1991), and 4,900 were taken in 1987 (ODFW, unpublished data). These catches occurred in a directed gill net fishery which has since been banned (P. Hirose, personal communication). Over past decades, commercial catch of green sturgeon in the Columbia River has averaged 1,440 fish (for the 1960s), 1,610 (1970s) and 2,360 (1980s); catch in recent years has been

2,200 fish (1990), 3,200 (1991) and 2,200 (1992) (ODFW, unpublished data). The Columbia River recreational catch has been consistently below 500 fish per year (ODFW 1991); catch in recent years has been 141 (1988), 84 (1989), 86 (1990), 22 (1991) and 73 (1992) (ODFW, unpublished data). Presently, in the Columbia River, green sturgeon are caught almost exclusively (and incidentally) in the fall salmon gillnet fishery in the lower river, below Bonneville Dam (ODFW 1991). Overall, fisheries in Washington and Oregon seem to have been taking 5,000-10,000 adult green sturgeon per year.

While numbers of fish taken by the fishery have shown no striking trends, sturgeon being caught have declined in size over the years. In the 1960s, mean size of sturgeon in the fishery ranged between 17 and 19 kg, while since 1980, mean weight has usually been between 12 and 14 kg (ODFW, unpublished data).

Klamath and Trinity Rivers. A small number of green sturgeon are probably taken in the sport fishery here, but the main harvest is by the Native American gillnet fishery. A small but possibly significant number are also taken in an illegal snag fishery. All these fisheries target sturgeon as they move up the river to spawn during spring and again on fish returning seaward through the estuary, during June-August (USFWS 1990). In the Native American fishery, mainly adult sturgeon (> 130 cm FL) are captured (mean length 179 cm FL in 1988). Data on this fishery exist only since 1980 and available harvest estimates (USFWS 1989; T. Kisanuki, personal communication) are biased low because some green sturgeon harvest occurs prior to the annual monitoring activities of the USFWS (T. Kisanuki, personal communication). Also, USFWS monitors only the sturgeon harvest on the Yurok Indian Reservation; catches by the Karuk and Hoopa tribal fishermen in the Klamath River basin are undetermined (T. Kisanuki, personal communication). With that in mind, the adult harvest estimates for the Klamath system range between 158 fish in 1987 to 810 in 1981, with a mean of 349 (USFWS 1989, 1990; T. Kisanuki, personal communication). Adult harvest estimates for 1990 and 1991 are 239 and 309 fish, respectively. There seems to be, as yet, no indication from the catches of any recent decline. However, the fishery for green sturgeon is likely to increase as increased restrictions are placed on the harvest of depleted salmon populations in the rivers.

2. Modification of spawning and rearing habitat

The limited information available indicates that green sturgeon spawn in the Sacramento River in deep water somewhere between Knights Landing and Red Bluff, which is probably lower in the drainage than they originally spawned. If they are like white sturgeon, strong year classes are produced episodically, when flows in the river are exceptionally high. Presumably, green sturgeon have a specific set of flow, depth, and substrate requirements for spawning and then for the early life history stages of their young. The flows and channel of the river have been highly modified, so it is likely that suitable conditions for spawning and rearing of green sturgeon occur less frequently now than they once did (pre-1940s), especially during or after periods of extended drought. It is also possible that juvenile green sturgeon once reared in the estuary although there is little evidence of this in recent times.

3. Entrainment

Juvenile green sturgeon and occasional adult sturgeon are entrained on an irregular basis in the fish facilities of the SWP and CVP. The numbers vary enormously from year to year and it is not known if the numbers represent a significant part of the population or not. It is likely that most green sturgeon captured at the pumping plants and returned to the Delta survive the experience, but the actual survival rate is not known. The discovery of a 5 adult and 33 juvenile green sturgeon in Clifton Court Forebay in 1992 is also a cause for concern because it is not known whether or not those fish were trapped there permanently.

4. Toxic substances

The effects of toxic substances from heavy metals to pesticides on green sturgeon are unknown. However, the fact that they spawn and rear in the Sacramento River and Delta indicates that high exposure levels are possible. The long-lived adults may accumulate contaminants through the food chain, which could interfere with reproduction.

Conservation measure: There currently is no active management of the green sturgeon population in the Sacramento-San Joaquin estuary, beyond what is deemed necessary to protect white sturgeon fishery. However, the California Fish and Game Commission in 1993 banned fishing for sturgeon along the North Coast, including the Klamath River although these regulations do not apply to the Native American gillnet fishery.

RESTORATION

Objective

The primary objective is to maintain a minimum population of 1,000 fish over 1 m TL each year, including 500 females over 1.3 m TL (minimum size at maturity), during the period (presumably March-July) when spawners are present in the estuary and the Sacramento River. The restoration of green sturgeon should not be at the expense of other native fishes, including white sturgeon. The 1,000 number was determined as being near the median number of green sturgeon estimated to be in the estuary during the 1980s. The total size of the adult green sturgeon population that uses the estuary may be larger than 1,000 because non-spawning adults may be in the ocean. D. Kohlhorst (personal communication) estimates that the total population is around 3,000 fish over 1 m.

Restoration Criteria

Green sturgeon will be considered restored in the Sacramento-San Joaquin estuary once the median population of mature individuals (1 + m TL) has reached 1,000 individuals (including 500 females over 1.3 m TL) over a 50 year period or for five generations (10 years is the minimum age of sexual maturity). If population estimates are less than 1,000 fish for more than three years in a row, the restoration period will be restarted. This definition is subject to revision as more information becomes available. Restoration will be measured by determining population sizes from tagging programs or other suitable means. The present sturgeon tagging programs, which focus on white sturgeon, are inadequate for determining accurately the abundance of green sturgeon. Therefore a median population goal of 1,000 fish over 1 m TL (including 500 females over 1.3 m) is achievable only if a monitoring program that focusses specifically on green sturgeon is in place. Thus the first restoration criterion will be establishment of an adequate population determination and monitoring program. Once that program is in place, the minimum population goal can be re-evaluated and a realistic, presumably higher, goal established. It may be desirable to have the numbers high enough to support the removal of a minimum of 50 fish over 1 m TL per year by a fishery (assuming an exploitation rate of 5% is sustainable).

6. SACRAMENTO SPRING-RUN CHINOOK SALMON

Oncorhynchus tshawytscha (Walbaum)

Introduction

Status: Sacramento spring-run chinook salmon (= spring chinook) are considered to be a Species of Special Concern by CDFG and a Sensitive Species by the US Forest Service in California. A petition to the National Marine Fisheries Service to list California populations (Klamath and Sacramento) as endangered species has been held in abeyance to allow attempts to restore spring chinook populations to precede without formal listing (G. Thomas, Natural Heritage Institute, personal communication).

Restoration potential: Spring chinook are a distinctive run of salmon with a high degree of threat but also high restoration potential.

Description: Spring chinook are large salmonids, reaching 80-110 cm SL and weighing 9-10 kg or more. They have 10-14 major dorsal fin rays, 14-19 anal fin rays, 14-19 pectoral fin rays, and 10-11 pelvic fin rays. There are 130-165 lateral line scales and 13-19 branchiostegal rays on either side of the jaw. The gill rakers are rough and widely spaced, with 6-10 rakers on the lower half of the first gill arch. Spring chinook are silvery in color when migrating upstream but gradually turn darker through the summer. Reproductive adults are uniformly olive brown to dark maroon, but males are darker than females and have a hooked jaw and snout and an arched back. Chinook salmon are distinguished from other species of salmonids by body coloration, specifically spots on the back and tail and the solid black color of the lower gum line. Parr generally have 6-12 parr marks, evenly spaced and centered along the lateral line. The adipose fin of the parr is pigmented along the upper edge but clear at the base. The other fins are clear, except for the dorsal, which may be spotted.

Taxonomic Relationships: The runs of chinook salmon in California are differentiated by the maturity of fish entering fresh water, time of spawning migrations, spawning areas, incubation times, incubation temperature requirements, and migration timing of juveniles. Differences in life histories effectively isolate spring chinook salmon from other runs; thus, the traits are undoubtedly inherited. Allozymic differences between inland populations of California chinook salmon also have been observed, with various degrees of differentiation between rivers within drainages and between drainages (Bartley and Gall 1990). Therefore, each run of salmon could be considered genetically distinct to some degree, in some cases even from other runs in the same stream. There seem to be two distinct spring-run chinook populations (stocks) in California: a Sacramento-San Joaquin population and a Klamath-Trinity population. In spite of possibility of some mixing of the stocks in the ocean, the large distance separating the spawning streams of these two populations justifies their being considered, and managed as, separate evolutionarily significant units (gene pools). Populations that probably existed in smaller coastal streams, such as the Eel River, have been extirpated.

Distribution: Spring chinook salmon are found in rivers in British Columbia, Washington, Idaho, Oregon, and California, but their populations are depleted throughout this range or maintained by hatchery production (Shepherd 1989). Spring-run chinook also occur in substantial populations in Alaska (Healey 1991), but their genetic affinities with more southern populations are unclear. In California, spring chinook were once abundant in all major river systems. There were large populations in at least 26 streams in the Sacramento-San Joaquin drainage and at least 20 streams in the Klamath-Trinity drainage (CDFG 1990). Spring chinook are now reduced to scattered populations in the Klamath, Trinity, and

Sacramento drainages (Campbell and Moyle 1991), with small numbers (probably strays) found on occasion in the Smith River, Redwood Creek, Mad River, Mattole River, and Eel River. There is no evidence of recent spawning in the latter five rivers.

In the Sacramento-San Joaquin drainage, principal holding and spawning areas were in the middle and headwater reaches of the San Joaquin, Feather, upper Sacramento, McCloud, and Pit rivers, presumably with smaller populations in most of the other tributaries large and cold enough to support the salmon through the summer. The main populations were all extirpated when dams were constructed that blocked access to the holding areas, primarily in the 1940s and 1950s (but starting in the 1890s). Today, the most consistent self-sustaining wild populations in the drainage are in Deer and Mill creeks, Tehama County, with a few fish present in Antelope, Battle, and Big Chico creeks in some years (Vogel 1987a,b, Sato and Moyle 1988). Substantial numbers of spring chinook can also be present in Butte Creek, but numbers have been highly variable (100-1,500 fish between 1982 and 1992) and it is not certain if this is a self-maintaining population. Juveniles from the CDFG Feather River Hatchery have been planted there in the past (including 1984 and 1985), and because Pacific Gas & Electric (PG&E) diverts Feather River water into Butte Creek for power production, Feather River Hatchery fish may be attracted to it. Spawning habitat is largely lacking in the reaches above Centerville, but there are adequate spawning gravels and holding pools in the lower reaches. Natural reproduction in Butte Creek may nevertheless be disrupted by regulated flow regimes (the stream is regulated for hydroelectricity), high temperatures, poaching, and other human disturbance. Historically, Butte Creek apparently had very small runs of spring chinook (Clark 1929). However, in 1989 large numbers of spring chinook occupied Butte Creek and these fish apparently were derived from natural spawning in the creek (F. Meyer, CDFG, personal communication). In the Feather River, a run of fish labelled as spring-run is maintained by hatchery production. In 1986, for example, 1,433 adults were captured and over 1.6 million fingerlings were planted (Schlichting 1988). These fish also may stray into the Yuba River, where apparent spring chinook have been observed in the cold water below Engelbright Reservoir. However, coded wire tag returns indicate that fish labeled as spring-run and fall-run at the hatchery are thoroughly mixed so there is little reason to regard the Feather River fish as the same fish as wild spring chinook (F. Fisher, CDFG, personal communication).

Habitat Requirements: For spring chinook adults, numbers holding in an area seem to depend on the volume and depth of pools, amount of cover (especially bubble curtains created by inflowing water), and proximity to patches of gravel suitable for spawning (G. Sato, BLM, unpublished data). Mean water temperatures in pools where adult chinook held during the summer of 1986 in Deer and Mill creeks were 16°C (range 11.7-18°C) and 20°C (range 18.3-21.1°C), respectively, and for juveniles in Mill Creek the temperature ranged from 13.3-22.2°C (Sato and Moyle 1988). Records indicate that spring chinook in the Sacramento-San Joaquin River system spend the summer holding in large pools where summer temperatures are usually below 21-25°C (Moyle 1976). Sustained water temperatures above 27°C are lethal to adults (Cramer and Hammack 1952). Pools in which the adults hold are at least 1-3 m deep, with bedrock bottoms and moderate velocities (G. Sato, unpublished data; Marcotte 1984). In Deer Creek, preferred mean water velocities measured during 1988 were 60-80 cm sec^{-1} for adults (Sato and Moyle 1988). The pools usually have a large bubble curtain at the head, underwater rocky ledges, and shade cover throughout the day (Ekman 1987). The salmon will also seek cover in smaller pocket water behind large rocks in fast water. Habitat preference curves determined by USFWS for adult chinook in the Trinity River indicate that pool use declines when depths become less than 2.4 m and that optimal water velocity ranges between 15-37 cm sec^{-1} (Marcotte 1984).

Spawning occurs in gravel beds that are often located at tails of holding pools. Optimum substrate for embryos is a mixture of gravel and rubble (mean diameter 1-4 cm) with less than 25 percent fines (less than 6.4 mm diameter) (Platts *et al.* 1979, Reiser and Bjornn 1979). Optimal temperatures for development are 5-13°C. Newly emerged fry congregate in shallow, low velocity edgewater, especially in areas where organic debris provides a background that makes the juveniles difficult to see (Moyle unpublished data). Juveniles in Deer Creek were found to prefer runs or riffles with gravel substrates, depths of 20-120 cm, and mean water-column velocities of 20-40 cm sec^{-1} (Sato and Moyle 1989).

Life History: In general, spring chinook salmon migrate considerable distances up streams to spawn. They enter the rivers from March through June, the period of snow-melt flows. Historically, these migrating fish were a mixture of age classes ranging from two to five years old. At the present time a majority of the fish are probably three-year olds. While migrating and holding in the river, spring chinook do not feed, relying instead on stored body fat reserves for maintenance and for gonadal maturation. The runs also may be bimodal, with some fish holding downstream to migrate later in the summer, possibly because of increasing water temperatures later in the spring (Marcotte 1984). They are fairly faithful to home streams in which they were spawned, using visual and chemical cues to locate these streams. However, some may become disoriented, especially during high-water years, and ascend other streams.

When they enter fresh water, spring chinook are immature; their gonads mature during the summer holding period (Marcotte 1984). In Deer and Mill creeks, spawning occurs from late August through October. Eggs are laid in large depressions (redds) hollowed out in gravel beds. The embryos hatch following a 3-5 month incubation period and the alevins (sac-fry) remain in the gravel for another 2-3 weeks. Once their yolk sac is absorbed, juveniles emerge and begin feeding. In Deer and Mill creeks, Tehama County, juvenile salmon, during most years, spend 9-10 months in the streams, although some may spend as long as 18 months in fresh water (F. Fisher, personal communication). By the end of summer, they are 8-10 cm SL (Moyle, unpublished observation). Their main food during this period is drifting aquatic insects. Most of these juveniles seem to move downstream in the first high flows of winter in November through January, although some may persist through March (F. Fisher, personal communication). In the Sacramento River, most downstream movement seems to take place in December-February as parr (Vogel and Marine 1991). Outmigrants may spend some time in the Sacramento River or estuary to gain additional size before smolting and going out to sea but most have presumably left the system by mid-May. Once in the ocean, salmon are largely piscivorous and grow rapidly, reaching 80-100 cm SL in 2-3 years. Apparently, most spring run chinook mature at age 3, which accounts for their somewhat smaller average size and lower fecundity (ca. 4000 eggs/ female) than fall-run or late-fall-run chinook salmon (F. Fisher, personal communication).

Adult spring chinook migrate up Deer and Mill creeks from April through June (Vogel 1987a,b) and aggregate in the upper reaches (Airola and Marcotte 1985). In Deer Creek, most hold and spawn between the Ponderosa Way bridge and upper Deer Creek falls, which apparently is a barrier to migrating fish (Marcotte 1984). In Mill Creek they hold and spawn between the Little Mill Creek confluence and approximately 1.6 km above the Highway 36 bridge, with about 80 percent of this spawning habitat being within the Lassen National Forest boundary (Marcotte 1984).

There does not appear to be a diurnal pattern to migration, but surges in movements seem to occur after rain sufficient to cause a slight discoloration in the water following a period of clear weather; surges also occur when there is a sudden increase in water temperature (Cramer and Hammack 1952). When daytime water temperatures reach about 27°C, fish usually hold in cooler water in deep pools and migrate upstream at night. Fish hold in deep pools in upstream reaches during the summer and spawn in early fall. Pre-spawning activity has been observed by mid-August, and intensive redd-building activity and spawning occurs from the last week of August through the end of October (Parker and Hanson 1944; F. Fisher, personal communication) although in Deer Creek spawning is generally completed by late September (Moyle unpublished observation). Usually, spawning first occurs in the upper reaches of streams and subsequently in lower reaches, as water temperatures decrease (Parker and Hanson 1944).

Spawning salmon usually are well distributed within a stream section, reducing competition for redd sites (Cramer and Hammack 1952). Nests average 4 m^2 (42 ft^2, n = 87) in area.

Historically, the spawning population probably included many large fish that were four or five years old. Today, as the result of intense ocean fishing that removes the largest fish, such fish are much less abundant and runs are now almost entirely three-year-old fish.

Abundance: Spring-run chinook salmon of the Sacramento-San Joaquin River system historically comprised one of the largest runs on the Pacific coast. Commercial gillnet fishery landings of spring chinook in the Central Valley exceeded 600,000 fish in 1883 (California Fish and Game Commission 1885). Runs in the San Joaquin River alone probably exceeded 200,000 fish at times and it is likely that an equal number of fish were once produced by the combined spring runs in the Merced, Tuolumne, and Stanislaus rivers. However, early historical population levels were never measured (CDFG 1990). In 1955, CDFG estimated that with proper water management the San Joaquin drainage could still produce about 210,000 wild chinook salmon per year, with fall-run chinook replacing the spring-run populations lost to dam construction (CDFG 1955). The last large run in the San Joaquin River occurred in 1945, when 56,000 fish made it up the river (Fry 1961). The San Joaquin River spring chinook run has since been extirpated, primarily due to the dewatering of the lower San Jaoquin River following construction of Friant Dam in 1948, as well as blockage by the dam of access to upstream areas (Warner 1991).

After the demise of the San Joaquin stocks, Sacramento River spring chinook salmon constituted the most abundant natural runs in the Central Valley. As in the San Joaquin drainage, these spring chinook populations were also drastically reduced following construction of barrier dams. Historic run sizes for tributaries to the Sacramento River were estimated by CDFG (1990) to be: 15,000+ above Shasta Dam (McCloud River, Pit River, Little Sacramento River); 8,000-20,000 in the Feather River above Oroville Dam; 6,000-10,000 in the Yuba River above Englebright Dam; and 10,000+ in the American River above Folsom Dam. The Sacramento River drainage as a whole is estimated to have supported spring chinook runs exceeding 100,000 fish in many years between the late 1800s and 1940s (Campbell and Moyle 1991) but these estimates may be low by a factor of 3 or 4 (F. Fisher, personal communication).

The decline of spring chinook in the Sacramento drainage began when spawning streams were disrupted by gold mining and irrigation diversions. The decline accelerated following closure of Shasta Dam in 1945 which cut off access to major spawning grounds in the McCloud, Pit, and upper Sacramento rivers. In recent years the decline has continued. Estimates by CDFG of spawning escapement in the mainstem Sacramento River ranged from 3,600 to 25,000 fish between 1969 and 1980, with an average population of 17,000 fish per year (Marcotte 1984). However, most of these fish probably originated in the Feather River Hatchery and were therefore mixed fall and spring run stock. In Deer and Mill creeks, estimates of spawning fish averaged 2,300 and 1,200 fish, respectively (Marcotte 1984). Since 1985, combined yearly totals for both creeks have been less than 900 fish, with the exception of 1989 when there were about 1,300 fish (Table 5.1). Spawning populations in other tributary streams are considerably less, with an estimated 40-100 fish (incomplete survey in 1983) in Antelope Creek (Airola 1983). Spring chinook numbers in Antelope Creek have dropped during the last few years to < 10 individuals per year (Campbell and Moyle 1991; E. Gerstung, CDFG, personal communication). Up to 100 fish have held in Big Chico Creek (Marcotte 1984), but that stream currently supports a much smaller run of probably less than 20 adults (E. Gerstung, personal communication). In Butte Creek, numbers have fluctuated considerably from year to year and in the past have been augmented by fish from the Feather River Hatchery. However, about 1,300 adults held in the creek in both 1988 and 1989. These may have resulted from natural reproduction, but it is also possible that they were fish from the Feather River Hatchery attracted to the creek by Feather River water PG&E diverts into the creek to run their power house. Recent counts in Butte Creek have dropped to 300+ fish (in 1990), 100+ (1991), and 300+ (1992) (E. Gerstung, unpublished data).

During the pre-dam period, spatial segregation of runs by downstream and upstream spawning sites maintained their genetic integrity. When major dams began releasing cold water into lower reaches of the main rivers, spring chinook began to over-summer and spawn in what had been exclusive fall chinook spawning habitat. As a consequence, spring chinook in the Sacramento River have interbred with fall-run fish (Vogel 1987a,b).

Overall population trends for spring chinook salmon in California are described by Campbell and Moyle (1991). They reported that more than 20 historically large populations of spring-run chinook have been extirpated or reduced nearly to zero since 1940. Four additional runs (Butte, Big Chico, Deer, and Mill creeks) have exhibited statistically significant declines during the same period. The only substantial, essentially wild populations of spring-run chinook remaining in California are in Deer and Mill creeks in the Sacramento drainage and in the Salmon River in the Klamath-Trinity drainage (Campbell and Moyle 1991). Other populations tend to be supported by hatchery stocks.

Reasons for decline: For spring chinook, historic population declines are attributable mainly to loss of upstream habitat and secondarily to harvest, yet it is highly likely that losses of migrating fish, both juveniles and adults, in the estuary have contributed significantly to their decline. The causes of the continuing decline in recent decades are poorly understood but are probably related to poor survival of out-migrants, especially in the Delta, limited access of adults to upstream spawning areas, especially in dry years, poaching and other forms of harvest, and other factors such as disease and dilution and introgression of wild stocks by interbreeding with hatchery-reared genotypes.

1. Habitat loss.

Because spring chinooks require access to cold upper reaches of Central Valley streams, their populations have been declining since the 1860s when many streams were mutilated by hydraulic mining for gold. Historically, however, the major factor responsible for the extirpation or decimation of spring chinook stocks has been the loss of spawning habitat due to the construction of barrier dams (CDFG 1990). Starting in 1894 with the construction of LaGrange Dam on the Tuolumne River, access to holding and spawning areas was increasingly blocked by dams diverting water for agricultural and urban use. The biggest barriers to spring chinook in central California, however, were Shasta Dam, closed in 1945, and Friant Dam, closed in 1948, which together denied spring chinook access to much of their remaining spawning and holding areas. Both dams were constructed without fish passage facilities and it was assumed that hatchery production would replace lost natural production of salmon. This assumption has proven to be false; hatcheries have mainly succeeded in slowing the decline of California's salmon populations and in substituting fall-run (or hybrid) hatchery fish for wild spring chinook.

Loss or degradation of habitat, stemming from water development, continues to be a problem. Within the Central Valley, water diversions during dry years may dewater the lower reaches of spring chinook salmon streams (e.g. Deer and Mill creeks) during spring and summer, thereby blocking both upstream migration of adults and downstream migration of juveniles (CDFG 1990). Low stream flows can also result in elevated summer temperatures in spring chinook holding areas. Such conditions in the South Fork Trinity and Salmon rivers (Klamath drainage), for example, have apparently lead to increased adult mortality and decreased spawning success (CDFG 1990).

2. Harvest

Spring chinook stocks are harvested in both ocean and in-river fisheries. Although fisheries capture mainly hatchery fish, they are presumably also taking wild fish at least in proportion to their abundance relative to hatchery fish. Given the small size of remaining runs of wild fish, the take of even a few wild fish may have a significant effect on their populations; it is likely that as many as one-half of the wild fish are taken in fisheries, mainly commercial fisheries. Sport fisheries accounted for an average of 300 fish (annual range 40-900 fish) during 1975-1984 in the upper Sacramento River but it is not known if many of these were wild fish headed for the tributaries.

Returns of coded-wire tags indicate that upper Sacramento River stocks and Klamath system stocks have different ocean distributions. The former are concentrated between Point Arena and Morro Bay and the latter are most abundant north of Point Arena to Cape Blanco, Oregon (CDFG 1990). Accordingly, Klamath stocks probably have been less affected by ocean fisheries because of harvest constraints placed on Northern California and southern Oregon fisheries under the auspices of the Pacific Fishery Management Council. In contrast to the consequent reduced landings in the Klamath Management Zone, the harvest rate index for Central Valley chinook stocks generally has increased in recent years, although it decreased in 1991 (A. Baracco, CDFG, personal communication). Total harvest estimates of spring-run chinook, based on fingerling releases by the Trinity River Hatchery (for 1976-1984 broods), are: ocean fisheries 0.30; in-river fisheries 0.12; combined fisheries 0.42 (CDFG 1990). Harvest-rate estimates based on age-three ocean recruits (potential adults) indicate that roughly half of hatchery-produced adults are harvested by fisheries (CDFG 1990). Based on coded-wire tag data from the Trinity River and Feather River hatcheries, spring-run chinook salmon are harvested by the ocean commercial fishery at a rate somewhat less than fall-run chinook salmon because spring chinook are available (i.e., legal-sized) for a shorter period of time during the commercial season (CDFG 1990); they, however, tend to mingle in the ocean with the now more abundant fall-run stocks. In addition, the formerly unrestricted high-seas gillnet fishery for squid and other species may have reduced spring chinook stocks to an unknown, but possibly significant, degree.

Commercial fisheries may also be affecting chinook populations indirectly through the continual removal of larger and older individuals. This results in spawning runs made up mainly of three-year-old fish, which are smaller and therefore produce fewer eggs per female. Removal of older fish also removes much of the natural cushion the populations have against natural disasters, such as severe drought, which may wipe out a run in one year. Under natural conditions, four- and five-year-old fish still in the ocean help to keep runs balanced and can make up for fish lost. Under present conditions, a loss of a run in one year will result in very low runs three years later, and loss of runs two or three years in a row can potentially eliminate a population.

During the summer holding period in fresh water, many large adult salmon are caught by fishermen, some by poachers but others by anglers who snag them accidentally with spinning lures. The importance of this source of mortality is indicated by the distribution of the fish; they are most abundant in the more remote canyon areas, but scarce in pools close to roads.

3. <u>Outmigrant mortality</u>

Smolt mortality is probably a major factor affecting spring chinook abundance as it is for all runs of salmon in the Sacramento-San Joaquin drainage. Conditions in the rivers and Delta affect outmigrant mortality. Small numbers of outmigrants are entrained at every irrigation diversion along the Sacramento River that is operating during the migration period (November to January). Diversion into the Delta cross channel and Georgiana Slough results in greater smolt mortality because smolts are diverted into the Central Delta where they are more vulnerable to entrainment in SWP and CVP pumping plants. In the Delta, smolts are affected by a large number of diversions and reverse flows resulting from high pumping rates that extend the migration period and increase risk of loss to SWP and CVP pumps. When pumping rates are high at the SWP and CVP pumping plants, and outflows are relatively low, spring chinook smolts are probably entrained in large numbers, are consumed by predators in Clifton Court Forebay and other off-channel areas, or are otherwise diverted from their downstream migration.

4. Hybridization with fall chinook

Interbreeding of wild spring chinook with both wild and hatchery fall chinook has the potential to dilute and eventually eliminate adaptive genetic distinctiveness of the few remaining naturally reproducing stocks (e.g., Mill Creek, Deer Creek). Spring and fall runs of chinook salmon were previously well separated by time and spawning area. Construction of dams eliminated ancestral spawning areas of spring chinook in upper reaches of streams, forcing those runs to use lower elevation areas utilized also by fall-run fish. Differences in run timing also have decreased, thereby increasing the likelihood of genetic mixing (CDFG 1990). Because flow of the Sacramento River is regulated by Shasta Dam and other dams, cold water is present in some areas throughout the summer, which may allow greater temporal overlap and, hence, hybridization of different runs in the Sacramento drainage. At the Feather River Hatchery, spring-run fish were kept separate from other runs by assuming that all salmon taken there before October 15 were spring-run chinook salmon and fish taken after this date were fall-run fish (F. Fisher, personal communication). There is now strong evidence spring and fall stocks inadvertently have been hybridized at the hatchery and now form just one hatchery strain. In the wild, hybridization between hatchery and wild fish almost certainly has occurred in the Sacramento River, Feather River, Yuba River, and, perhaps, Butte Creek (Campbell and Moyle 1991).

The potential threat of mixed stock spring chinook to the remaining wild spring chinook is indicated by the fact that in both the Sacramento and Klamath-Trinity drainages, the majority of spring-run chinook salmon are the result of hatchery spawning. Production of presumptive spring-run chinook juveniles at the Feather River Hatchery ranged between 2-3 million fish, while annual adult runs ranged between 800-7,200 fish during 1980-1989. However, mixing of spring-run and fall-run stocks at the hatchery has compromised the genetic character of spring-run fish (CDFG 1990).

5. Disease

The impact of disease cannot be ruled out as a factor in the recent decline of spring-run chinook salmon. Bacterial kidney disease (BKD) recently was found in all hatchery-reared smolts that were released from the Trinity River Hatchery and had been in residence in the Trinity River for several months, although there was no evidence of disease in the hatchery stock itself (P. Higgins, personal communication). BKD and perhaps other diseases such as infectious hematopoietic necrosis (IHN) could seriously curtail the ability of hatchery operations to bolster production if hatchery fish are susceptible to infection after release in the wild. Disease(s) originating from hatchery fish may also be a factor in depressing wild stocks. Whether or not disease is affecting wild spring chinook in the Sacramento system is not known and should be investigated.

Conservation measures: There is intense interest in spring chinook salmon on the part of agencies, environmental groups, and commercial fishermen because of its historical abundance and because formally listing it as an endangered species would have severe negative effects on the salmon fishery in general. As a result considerable efforts are being made to manage this run at the present time, although additional effort will be needed for restoration.

Recent stock assessment and restoration efforts for spring chinook salmon are conducted by the State (CDFG 1990). Those efforts include annual surveys of runs, a newly instituted habitat restoration program, enforcement of fishing regulations, installation and maintenance of fish screens and fish ladders, and development and coordination of appropriate water-use plans for specific areas. Within the Sacramento River system, efforts to negotiate changes in water management have resulted in expanded spawning and rearing habitat in Butte Creek, and similar efforts are reportedly in progress for Mill Creek, Deer Creek, and the Yuba River.

The most important remaining natural populations in the Sacramento drainage are in Deer and Mill creeks. During wet or normal years, natural flows are sufficient to enable salmon to surmount diversion dams in the lower reaches of these streams and reach holding pools. In dry years, however, diversions of water for irrigation may decrease flows in the lower reaches to such an extent that adults are unable to negotiate dams. Because diversions are on private land and represent long-held water rights, this problem can only be solved with cooperation of local landowners or by water-rights acquisition. Since 1989, an agreement between DWR, Los Molinos Water Company, The Nature Conservancy, and CDFG has provided water pumped from wells on the Dye Creek Preserve to Tehama County farmers, so that less water would be diverted for agricultural irrigation from Mill Creek. This strategy appears to have been highly successful in maintaining flows in Mill Creek for salmon (A. Weinstein, The Nature Conservancy, personal communication; CDFG, April 1, 1992 memorandum from S. Capello to S. Ford, DWR).

In the Delta, the recent (May 1992) decision by CDFG to halt striped bass planting and predator removal program in Clifton Court Forebay will probably benefit spring-run chinook populations by reducing predation on outmigrants.

At the present time, a Spring Chinook Work Group, consisting of representatives of various agencies, commercial fishermen, farmers, and others affected by spring chinook conservation efforts are attempting to devise a recovery plan for spring chinook in the upstream habitats of the Sacramento drainage (L. Davies, UCD, personal communication). It is assumed that if this group can agree to recovery measures, the measures will be adopted by the agencies concerned. Restoration measures being considered include: (1) providing passage of adults to holding and spawning areas, (2) protecting adults in the holding pools, (3) creating additional habitat by improving access to Antelope, Begum, and South Fork Cottonwood creeks, (4) improving management of Butte Creek for wild salmon, (5) providing passage flows for out-migrating juveniles, (6) providing better instream habitat for juvenile fish, (7) reduction in take by fisheries, (8) reducing effects of hatchery fish on wild populations, and (9) increased protection in the Delta.

RESTORATION

Restoration Objective

The objective is to restore wild populations of spring chinook salmon to optimum levels that can be supported by holding and spawning habitat in tributary streams to the Sacramento River (especially in Deer and Mill creeks, Tehama County) by improving outmigrant conditions in the Delta. Any improvements upstream or in ocean fishery regulations will be greatly negated if protections in the Delta are not implemented concurrently, especially during November through January when Deer and Mill Creek smolts migrate. Therefore, the objective of this plan is to restore survival rates of outmigrating smolts to levels that existed before the construction of the pumps of the CVP and SWP in the south Delta. Measures taken to protect migrating adult and juvenile spring chinook salmon should not be made at the expense of measures taken to protect other native fishes in the system, including other runs of chinook salmon.

Restoration Criteria

Sacramento spring-run chinook salmon will be regarded as restored when (1) self-sustaining populations in excess of 500 spawners are present in both Deer and Mill creeks; (2) the number of wild spawners in Sacramento River tributaries reaches a mean number of 8000 fish and does not drop below 5000 fish, for 15 years, three of which are dry or critical years and (3) when the smolt survival rates between Sacramento and Chipps Island approach pre-project levels when the number of adults in the tributary streams is less than 5000. Restoration will be measured by three interacting criteria: (1)

presence of self-sustaining spawning populations in Deer and Mill creeks, Tehama County; (2) total number of spawners in Deer, Mill, Antelope, Butte, Big Chico, Begum, South Fork Cottonwood, and Clear creeks and (3) smolt survival rates through the Delta. The number of spawners can be estimated by carcass and redd counts, but smolt survival cannot yet be satisfactorily estimated. These restoration goals can be achieved only if there is simultaneously improvement in conditions in spawning and rearing streams, in the Delta for passage of juveniles and adults, and improved management of the fishery to allow for increased survivorship of adults during periods of low population size.

Deer and Mill creeks: These two streams are largely unregulated streams that support the largest remaining populations of unquestioned wild spring-run chinook. Thus these two populations must be maintained as self-sustaining entities to provide a minimum level of protection for the wild fish. Based on historic (pre-1976) records, the number of salmon in each stream should not drop below 500 fish, with a three-year running average of no less than 1,000 fish (Table 5.1). While a fairly substantial population of salmon exists in Butte Creek, long-term sustainability of the population in a regulated stream is questionable, as is its relationship to the hatchery-maintained "spring" run population in the Feather River.

Number of spawners: Spring chinook will be regarded as recovered when the number of spawners in tributary streams to the Sacramento drainage exceeds 5,000 fish each year over a 15-year period (five generations X three-year life cycle), with 3 of the 15 years being dry or critical years. The average number of natural spawners of wild origin over the 15-year period must not be less than 8000 fish. If the Yuba River proves to still have a natural run of spring chinook, this population goal should be raised by whatever number of spawners it is estimated that the stream can support. The total population goal assumes an equal (or nearly equal) sex ratio and that 90% or more of the females are age 3 or older. It does not include fish found in the Feather River or mainstem Sacramento River or those taken by the Feather River hatchery for artificial spawning. This number is a tiny fraction of the 500,000 to 1 million spring chinook that once spawned in the Central Valley but represents a reasonable number of spawners that can be supported in Sacramento River tributaries (F. Fisher, personal communication).

Smolt survival rate: The principal means for measuring suitability of habitat conditions for juvenile chinook salmon in the Delta is to have smolt survival rates between Sacramento and Chipps Island be equivalent to what they were prior to the present configuration of the CVP and SWP (i.e., 1940s level of development, USFWS 1992). Accurately measuring smolt survival rates is extremely difficult, so this cannot be used as a criterion for restoration until adequate methods of estimating survival are developed (something which should be done as part of the restoration process). Ideally, the survival rate should be based on mark-recapture studies of smolts of similar size released during the principal outmigration period. Because Deer and Mill Creek outmigrants enter the Delta as yearlings during November through January, this time period will be the most important to evaluate. However, hatcheries do not release spring-run during this time period, so late fall-run hatchery production may need to be used as a surrogate for the mark-recapture studies. Until reliable measures of survival rates are developed, the principal means for measuring restoration will be distribution and number of spawning adults. Once the criterion is developed, it should be used primarily in conjunction with adult criteria. When adult numbers drop below 5,000, smolt survival rates through the Delta the following year should be higher than would be permitted when adult numbers are higher. If possible, a sliding scale of minimum survival rates based on adult numbers should be developed.

Table 6.1. Population counts and estimates of spring-run chinook salmon from Deer and Mill creeks. (Data based on counts at diversion dam ladders and spawning surveys conducted by CDFG and US Forest Service.)

Year	Deer Creek	Mill Creek
1954	NE[1]	1789
1955	NE	2967
1956	NE	2233
1957	NE	1203
1958	NE	2212
1959	NE	1580
1960	NE	2368
1961	NE	1245
1962	NE	1692
1963	1702	1315
1964	2874	1539
1965	NE	NE
1966	NE	NE
1967	NE	NE
1968	NE	NE
1969	NE	NE
1970	2000	1500
1971	1500	1000
1972	400	500
1973	2000	1700
1974	3500	1500
1975	8500	3500
1976	NE	NE
1977	467	563
1978	1200	925
1979	NE	NE
1980	1500	500
1981	NE	NE
1982	1500	700
1983	400	200
1984	NE	191
1985	300	291
1986	543	291
1987	200	90
1988	371	572
1989	77	556
1990	458	844
1991	448	319
1992	209	385

[1] NE = no estimate

7. SACRAMENTO LATE FALL-RUN CHINOOK SALMON

Oncorhynchus tshawytscha (Walbaum)

Introduction

Status: The Sacramento late fall-run chinook salmon (late-fall chinook) has no special protection although Moyle *et al.* (1993) recommend that it be listed by CDFG as a Species of Special Concern.

Restoration potential: This run is regarded as having a moderate degree of threat but low restoration potential.

Description: Late fall-run chinook salmon are morphologically similar to spring-run chinook. They are, on average, the largest of the four runs of chinook salmon in the Sacramento River, reaching 80-110 cm SL and weighing up to 9-10 kg or more. They have 10-14 major dorsal fin rays, 14-19 anal fin rays, 14-19 pectoral fin rays, and 10-11 pelvic fin rays. There are 130-165 lateral line scales. Branchiostegal rays number 13-19 on either side of the jaw. The gill rakers are rough and widely spaced, with 6-10 rakers on the lower half of the first gill arch. Reproductive adults are usually uniformly olive-brown to dark maroon; males are darker than females and have a hooked jaw and snout and an arched back. Some reproductively mature females have been observed to retain their silvery (ocean) coloration even during spawning (K. Marine, personal communication). Chinook salmon are distinguished from other species of salmonids by body coloration, specifically spots on the back and tail and the solid black color of the lower gum line. Parr generally have 6-12 parr marks, evenly spaced and centered along the lateral line. The adipose fin of the parr is pigmented along the upper edge but clear at the base. The other fins are clear, except for the dorsal, which may be spotted.

Taxonomic Relationships: The runs of chinook salmon in California are differentiated by the maturity of fish entering fresh water, time of spawning migrations, spawning areas, incubation times, incubation temperature requirements, and migration of juveniles. Allozymic differences between inland populations of California chinook salmon have also been observed, with various degrees of differentiation between rivers within drainages and between drainages (Bartley and Gall 1990). Therefore, each run of salmon could be considered to be genetically distinct to some degree, in some cases even from other runs in the same stream.

Distribution: Late-fall chinook are found mainly in the Sacramento River, and most spawning and rearing of juveniles takes place in the reach between Red Bluff and Redding (Keswick Dam). According to Vogel and Marine (1991), however, up to approximately 15-30 percent of the total late-fall run can spawn downstream of Red Bluff when "water quality is good". R. Painter (CDFG, personal communication) indicated that apparent late-fall chinook have been observed spawning in Battle Creek, Cottonwood Creek, Clear Creek, Mill Creek, Yuba River and Feather River, but these are at best a small fraction of the total population. Battle Creek spawners are presumably derived from an artificially maintained run from the Battle Creek Fish Hatchery. The historic distribution of late-fall run is not known, but it probably originally spawned in the upper Sacramento River and major tributaries in reaches now blocked by Shasta Dam. Some spawning may also have taken place in major tributaries to the San Joaquin River.

Habitat Requirements: The specific habitat requirements of late-fall chinook have not been determined, but they are presumably similar to other chinook salmon runs (see spring-run chinook salmon account) and fall within the range of physical and chemical characteristics of the Sacramento River above Red Bluff.

Life History: The great majority of late-fall chinook salmon appear to spawn in the mainstem of the Sacramento River (R. Painter, personal communication), which they enter from October through February (Vogel and Marine 1991). In the past, these migrating fish were a mixture of age classes ranging from two to five years old. At the present time a majority of the fish are three- and four-year olds. While migrating and holding in the river, late-fall chinook do not feed, relying instead on stored body fat reserves for maintenance. Spawning occurs in January, February and March, although it may extend into April in dry years. Eggs are laid in large depressions (redds) hollowed out in gravel beds. The embryos hatch following a 3-4 month incubation period and the alevins (sac-fry) remain in the gravel for another 2-3 weeks. Once their yolk sac is absorbed, the fry emerge and begin feeding on aquatic insects. All fry have emerged by early June. The juveniles hold in the river for about six months before moving down to the Delta in October through December. They may hold in the Delta for varying lengths of time, emigrating to the ocean in December through March (F. Fisher, personal communication). Once in the ocean, salmon are largely piscivorous and grow rapidly.

Because of their relatively large size, late-fall run chinook have the highest fecundity of any of the Sacramento runs of salmon, with females averaging around 6,000 eggs (F. Fisher, personal communication).

Abundance: The historic abundance of late-fall chinook is not known because it was formally recognized as distinct from fall-run chinook only after Red Bluff Diversion Dam (RBDD) was constructed in 1966. To get past the dam, salmon migrating up the Sacramento River had to ascend a fish ladder in which they could be counted with some accuracy for the first time. The four chinook salmon runs present in the river (fall, late-fall, winter, spring) were revealed as peaks in the counts, although salmon passed over the dam during every month of the year. Like winter-run and spring-run chinook, their numbers have declined since counting began in 1967. In the first 10 years of counting (1967-1976) the run averaged about 22,000 fish; in the last 10 years of counting (1982-1991) the run averaged about 9700 fish (CDFG, unpublished data). There have been no counts of 20,000 fish or more since 1975, although 16,000 fish were counted in 1987. The run in 1991 was 7089 fish (USFWS 1992). Counts for 1992 and 1993 are not available because the gates at Red Bluff Diversion Dam have been opened to allow free passage for winter-run chinook adults and smolts. Consequently, counting adult migrants is no longer possible.

Reasons for decline: Late fall-run chinook salmon have declined from historic numbers largely as the result of factors in upstream areas, but restoration of the run will depend on high survival rates of both adults and juveniles as they pass through the Delta. The causes of their population decline are poorly understood, but presumably are similar to those of winter-run chinook (Williams and Williams 1991) and spring-run chinook (this recovery plan). The principle causes of decline seem to be (1) passage problems over dams, (2) loss of habitat, (3) poor survival of outmigrating smolts, (4) excessive harvest, and (5) other factors such as disease and pollutants.

1. <u>Passage problems over dams</u>.

When Shasta and Keswick Dams were built in the 1940s, they presumably denied access to late fall-run chinook to upstream spawning areas where run-off and spring water originating from Mt. Shasta and other areas kept water temperatures cool enough for successful spawning, egg incubation and over-summer survival of juvenile salmon. The effects of Red Bluff Diversion Dam (RBDD) were more subtle and not recognized until fairly recently (Williams and Williams 1991). This dam apparently delayed passage to upstream spawning areas and also concentrated predators, increasing mortality on out-migrating smolts. Kope and Botsford (1990) documented that the overall decline of Sacramento River salmon was closely tied to the construction of RBDD. However, late-fall chinook salmon populations have failed to respond to raising of the gates of RBDD, despite their high fecundity (F. Fisher, personal communication).

2. Habitat loss or deterioration.

Large dams on the Sacramento River and its tributaries have not only denied salmon access to historic spawning grounds, but they have reduced or eliminated recruitment of spawning gravels into river beds below dams and altered temperature regimes. Loss of spawning gravels in the Sacramento River below Keswick Dam is regarded as a serious problem, and large quantities of gravel are now trucked to the river and dumped in, mainly to provide spawning sites for winter-run chinook. However, it is likely that late fall-run also use these gravel deposits (R. Painter, personal communication). Inadequate temperatures (too warm) can be a problem in this reach, mainly during drought years when flows are reduced to save water in Shasta Reservoir. Also, the reduced reservoir volume during drought years and the lack of a means to tap colder levels of the reservoir have meant that water released below the dam is often warmer than desirable. Efforts being made to provide cooler summer flows for winter-run chinook should also benefit late fall-run chinook.

3. Outmigrant mortality

Smolt mortality is probably a factor affecting late-fall chinook abundance as it is for all runs of salmon in the Sacramento-San Joaquin drainage. Small numbers of outmigrants may be entrained at every irrigation diversion along the Sacramento River that is operating during the migration period. At the same time, extensive bank alteration, especially rip-rapping, reduces the amount of cover available to protect the outmigrants from striped bass and other predators. Diking, dredging and filling in the Delta has reduced marsh, floodable and shallow habitat used by outmigrants and contributes mortality. When pumping rates are high at the SWP and CVP pumping plants, and outflows are low, late-fall chinook smolts may be entrained in large numbers, consumed by predators in Clifton Court Forebay and other off-channel areas, and otherwise diverted from their downstream migration.

4. Harvest

Studies of juvenile late fall-run chinook salmon with coded wire tags (from Coleman National Fish Hatchery) indicate that ocean harvest of these fish is intense. Harvest rates are difficult to determine accurately because most of the tagged late-fall chinook adults do not return to the hatchery, despite having been reared there; instead they remain in the Sacramento River and are trapped at Keswick (F. Fisher, personal communication). However, the limited data indicate that over 80% of late fall-run fish are harvested (F. Fisher, personal communication). This is not surprising because late-fall chinook tend to mature at older ages and larger sizes than other runs and have a late migration time; thus they are vulnerable to the ocean fishery at all times.

Commercial fisheries also may be affecting chinook populations indirectly through continual removal of larger and older individuals. This results in spawning runs made up mainly of smaller, three and four-year-old fish, which therefore produce fewer eggs per female. The removal of older fish also removes much of the natural cushion the populations have against natural disasters, such as severe drought, which may wipe out a run in one year. Under natural conditions, older fish still in the ocean help to keep runs balanced and can make up for fish lost during an occasional catastrophe. Under present conditions, a loss of a run in one year will result in very low runs three years later, and the loss of runs two or three years in a row can eliminate a population.

5. Pollution

A potential problem is the likelihood of a major spill of water laden with toxic chemicals from the Iron Mountain mine site, if the Spring Creek retention reservoir spills or bursts. These wastes could wipe out either migrating adults or, more likely, juveniles holding in the river.

Conservation measures: At present, less management is done to directly benefit late fall-run chinook salmon than any other run in the Sacramento River, mostly because the least is known about it. Fortunately, this run should benefit considerably from measures being made to enhance winter-run and fall-run chinook populations in the river. Restoration will require: (1) providing for passage of adults through the Delta to holding and spawning areas, (2) improving spawning success through habitat improvements and protection of adults from harvest on the spawning grounds, (3) providing passage flows for out-migrating juveniles, (4) providing habitat for juvenile fish in the river; (5) improving survival rates through the Delta; (6) reducing catch in ocean and stream fisheries, and (7) reducing the effects of hatchery fish on wild populations.

RESTORATION

Restoration Objective

The objective is to restore wild populations of late fall-run chinook salmon to optimum levels that can be supported by the remaining holding and spawning habitat in the Sacramento River by improving outmigrant conditions in the Delta. Any improvements upstream or in ocean fishery regulations will be greatly negated if protections in the Delta are not implemented concurrently, especially during October through December when smolts migrate. Therefore, the objective of this plan is to restore survival rates of outmigrating smolts to levels that existed before the construction of the pumps of the CVP and SWP in the south Delta. Measures taken to protect migrating adult and juvenile late fall-run chinook salmon should not be made at the expense of measures taken to protect other native fishes in the system, including other runs of chinook salmon.

Restoration Criteria

Sacramento late fall-run chinook salmon will be regarded as recovered when (1) the number of wild spawners in the Sacramento River reaches a mean number of 22,000 fish and does not drop below 15,000 fish, for 15 years, three of which are dry or critical years and (2) when the juvenile survival rates approach pre-project levels following years when adult populations are less than 15,000 fish in the Sacramento River. The number of spawners can be estimated by carcass and redd counts, while smolt survival cannot yet be satisfactorily estimated. The Team recognizes that these restoration goals can be achieved only if there is simultaneously improvement in conditions in the spawning and rearing streams, in the Delta for passage and rearing of juveniles, and improved management of the fishery to allow for increased survivorship of adults.

Number of spawners: Late fall-run chinook will be regarded as restored when the number of spawners in the Sacramento drainage exceeds 15,000 fish each year over a 15-year period (five generations X three-year life cycle), with 3 of the 15 years being dry or critical years. The average number of spawners over the 15-year period must not be less than 22,000 fish (the 1967-1976 average). The total population goal assumes an equal (or nearly equal) sex ratio and that 90% or more of the spawning females are age 3 or older. It does not include those fish taken by the Coleman National Fish Hatchery for artificial spawning. This number is a small proportion of the several hundred thousand late-fall chinook that once spawned in the upper Sacramento River drainage but represents the number of fish that probably existed in river at the time Red Bluff Diversion Dam was constructed (F. Fisher, personal communication).

Smolt survival rate: The principal means for measuring the suitability of habitat conditions for juvenile chinook salmon in the Delta is to have smolt survival rates between Sacramento and Chipps Island be equivalent to what they were prior to the present configuration of the CVP and SWP (i.e., 1940s level of development, USFWS 1992). Accurately measuring juvenile survival rates is extremely difficult, so this cannot be used as a criterion for restoration until adequate methods of estimating survival are developed (something which should be done as part of the restoration process). Ideally, the survival rate should be based on mark-recapture studies of juveniles of similar size released during the principal outmigration or Delta residence period. Until reliable measures of survival rates are developed, the principal means for measuring restoration will be distribution and number of spawning adults. Once the criterion is developed, it should be used primarily in conjunction with adult criteria. When adult numbers drop below 15,000, juvenile survival rates through the Delta the following year should be higher than would be permitted when adult numbers are higher. If possible, a sliding scale of minimum survival rates based on adult numbers should be developed.

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8. SAN JOAQUIN FALL-RUN CHINOOK SALMON

Oncorhynchus tshawytscha (Walbaum)

Introduction

Status: The San Joaquin fall-run chinook salmon (= San Joaquin fall chinook) does not have any special designation although CDFG recognizes it as a distinct stock.

Restoration potential: The degree of threat to San Joaquin fall-run is high, but it also has a high degree of restoration potential because of its increased reproductive success when flow conditions are favorable.

Description: Chinook salmon are large salmonids, reaching 75 to 100 cm SL, and weighing 10 kg or more, although individuals weighing more than 8 kg in the San Joaquin River are rare. They have 10-14 major dorsal fin rays, 14-19 anal fin rays, 14-19 pectoral fin rays, and 10-11 pelvic fin rays. There are 130-165 lateral line scales, and 13-19 branchiostegal rays on either side of the jaw. The gill rakers are rough and widely spaced, with 6-10 rakers on the lower half of the first gill arch. No distinctive meristic and morphological characters for San Joaquin fall run chinook are known. Reproductive chinook salmon adults are uniformly olive brown to dark maroon, but males are darker than females and have a hooked upper jaw and an arched back. Chinook salmon are distinguished from other species of salmonids by spots on the back and tail and by the solid black color of the gum line of the lower jaw. Parr generally have 6-12 parr marks, evenly spaced and centered along the lateral line. The adipose fin is pigmented along the upper edge but clear at the base. The other fins are clear, except for the dorsal, which may be spotted.

Taxonomic Relationships: The runs of chinook salmon in California are differentiated by the maturity of fish entering fresh water, time of spawning migrations, spawning areas, incubation times, incubation temperature requirements, and migration timing of juveniles. Differences in life histories effectively isolate fall chinook from other runs; thus, the traits are undoubtedly inherited. Allozymic differences between inland populations of California chinook salmon have also been observed, with various degrees of differentiation between rivers within drainages and between drainages (Bartley and Gall 1990). Therefore, each run of salmon should be considered to be genetically distinct to varying degrees. The genetic evidence for separation of Sacramento River fall chinook and San Joaquin River fall chinook is weak (Bartley and Gall 1990) and adults tagged as juveniles in Sacramento drainage hatcheries have been taken at the Merced River Hatchery (F. Fisher, CDFG, personal communication), indicating some mixing of the stocks takes place. Nevertheless, physical contrasts (e.g., flow, water temperatures, degree of habitat alteration) between the two drainage systems, the present small population size of the San Joaquin River stock, and the fact it is the only remaining run of salmon in the San Joaquin drainage, justify treating the San Joaquin fall-run as a distinct stock for management purposes. This is also the conservative course given the paucity of genetic data.

Distribution: Fall chinook salmon are found in rivers from California to Alaska and are presently the major run in California Central Valley streams. In the San Joaquin River system, San Joaquin fall chinook is the only salmon run remaining because spring chinook were eliminated from the system by the construction of impassible dams on major tributaries; the final extirpation took place with the closure of Friant Dam on the upper San Joaquin River. At present San Joaquin fall chinook are restricted to the three major tributaries of the San Joaquin River, the Stanislaus, Tuolumne, and Merced rivers. Within these river systems, spawning is confined to the upstream reaches below the first major dams.

Habitat Requirements: San Joaquin fall chinook require suitable habitat for upstream migration of adults, spawning, and rearing and outmigration of smolts. Requirements of upstream migrating adults include sufficient water flows to attract fish into spawning streams and for upstream passage to spawning areas. During upstream migration, water must be cool enough and have sufficient dissolved oxygen concentrations not to stress adult fish. Adult fish may delay upmigration if these requirements are not met. Spawning adults require gravel beds with gravel of a size that the fish can excavate (optimum is 2-11 cm). Eggs and alevins (sac-fry) require intragravel water flow while in the gravel, which is created when water velocities over the gravel are 30-90 cm/sec (Jensen 1972). Water should contain high concentrations of dissolved oxygen and be relatively cool (range of 5-13°C) for proper development of embryos and survival of alevins (Vogel and Marine 1991). Juvenile requirements include sufficient food and low enough temperatures (6-18°C) to allow growth and smoltification. In the lower San Joaquin River, out-migrating smolts are found in a wide variety of shallow-water habitats but disappear from these habitats (through death and migration) when temperatures exceed 18°C (McFarland and Weinrich 1987). Sufficient outflows and water temperatures are necessary to assure survival during outmigration of smolts to the ocean. Both are often lacking in the lower San Joaquin River during the outmigration period.

Life History: The life history of San Joaquin fall chinook is similar to that of other fall-run salmon. San Joaquin fall chinook generally begin arriving in the system in early fall. Salmon usually begin entering San Joaquin River tributaries by mid-October and are through spawning by mid-December. In the Tuolumne River, most spawning takes place in November, but has been observed from the last week in October through the last week in December (EAEST 1992). The majority of San Joaquin fall chinook return as three-year-old fish, but in some years the run may be dominated by two-year olds ("jacks"), both male and female (EAEST 1992). In the Tuolumne River, the percentage of females in recent years (1971-1988) has ranged from 25% to 67% and the number and size of females is regarded as a major factor limiting salmon production (EAEST 1992).

Females select suitable spawning sites on the basis of depth, water velocity, and gravel composition. In the Stanislaus River spawning occurs at mean depths of about 52 cm and at mean velocities of about 49 cm/sec (Aceituno 1993). Females excavate nests, or redds, and eggs are fertilized while being deposited in the nest. Spawning activities generally proceed in an upstream direction such that each successive egg pocket within a redd is covered by gravel from subsequent excavation activities. San Joaquin fall-run chinook females average fecundities of 2800 to 6700 eggs depending on age and size, with the estimated average number of eggs produced by a 3-year old female being 4,458; the equation for estimating fecundity is 109.4 times fork length (cm) minus 3200.2 (EAEST 1992).

Eggs incubate in the gravel for 10-12 weeks, depending on temperature. Alevins or sac fry then hatch but remain in the gravel for an additional month until the yolk sac is absorbed. Juveniles then emerge and feed on aquatic invertebrates for an additional 8-12 weeks until reaching 75-100 mm FL. From mid-March through early June juveniles undergo physiological changes (smolting) necessary for the transition from a freshwater existence to a saltwater existence and move down tributaries, into the San Joaquin River, and through the Sacramento-San Joaquin estuary to the ocean. In the Stanislaus River, small numbers of juveniles may remain through the summer and appear to emigrate in October or November (CDFG 1992a).

Survival rates of outmigrating smolts from the three tributaries are relatively low due to a combination of factors (EAEST 1992). In the rivers, predation by exotic species (centrarchid basses, etc.) can be a major problem in the lower reaches, especially if flows are low. When flows increase, outmigration time is more rapid and water clarity and temperatures are lower, which decrease the effectiveness of predators. In the San Joaquin River, high temperatures, low oxygen levels, inadequate shallow water habitat (cover), and exotic predators (e.g., striped bass) all contribute to high mortality rates. In the Sacramento-San Joaquin Delta the single biggest cause of mortality is the pumps of the CVP and SWP through direct entrainment, increased predation rates (e.g., in Clifton Court Forebay), and movement of smolts to unfavorable habitats, delaying outmigration.

Abundance: Pre-water development population levels of San Joaquin fall chinook are unknown. In 1955, CDFG estimated that with proper water management the San Joaquin River drainage could still produce 210,00 wild chinook salmon a year with fall chinook as the major run (CDFG 1955); however, production has never approached that level since records have been kept. Annual population surveys have been conducted on all tributaries since 1953 and on some tributaries since 1940 (Table 7.1). Over this period, populations have fluctuated in abundance. Higher returns of adult fish are strongly correlated with wet years. Similarly, low adult returns are correlated with normal, dry, and critically dry water years. Prior to 1990, spawning populations in the San Joaquin River drainage fell below 2,000 fish just three times (1962, 1963, and 1977). These low adult returns followed previous drought periods that extended for no more than three consecutive brood years. The 1987-1992 drought resulted in adult returns of less than 2,000 fish beginning in 1990 (1990 - 941 fish; 1991 - 717; 1992 - 1,377) but returns exceeded 2,000 (2,607) in 1993 (Table 7.1). The general trend in numbers of San Joaquin fall run chinook has been downwards (Figure 7.1) although large fluctuations in numbers can mask the trend for a number of years (e.g., 1981-1985).

Reasons for decline: Declines in San Joaquin fall chinook populations can be attributed to a number of factors. Within the San Joaquin River drainage the main factors are loss of access to upstream habitat because of construction of dams and reduced suitability of remaining habitat due to changes in land and water use practices, especially in combination with drought. Poor survival of outmigrants both in river and through the Sacramento-San Joaquin Delta also appears to be a significant factor. Poaching and legal harvest may also be factors, but are probably less important than migration passage, habitat, and smolt survival. Other factors such as introgression with hatchery stocks and the presence of pesticides and increased concentrations of naturally occurring chemicals due to agricultural practices may also be contributing factors.

1. Habitat loss.

Although there are no long-term records for pre-1950s populations of San Joaquin fall chinook it seems likely that significant declines began in the 1860s due to the detrimental effects of hydraulic gold mining operations on spawning grounds. Populations might have recovered from mining if not for the construction of dams which blocked access to upstream spawning areas. The first was La Grange Dam on the Tuolumne River, completed in 1894. Friant Dam on the San Joaquin River, completed in 1948, was the last major dam built with a major detrimental effect on salmon populations. In addition to blocking upstream access, water releases from Friant Dam were insufficient to provide upstream access to returning adult salmon, except in wet years (Moyle 1970), or to flush smolts downstream (Warner 1992). Thus, unlike the downstream tributary rivers, the San Joaquin River no longer supports salmon below the dam.

2. Suitability of habitat.

Dam construction was undertaken for a number of reasons but primarily for irrigation, flood control, and urban water supply. As a consequence, dam construction occurred at the same time that major changes in land and water use took place. Diversions of water primarily for agricultural use resulted in changes in hydraulic and temperature regimes. The resulting changes in physical conditions include sedimentation of spawning gravels, inadequate flows to attract returning adults to spawning streams, elevated temperatures inappropriate for egg incubation and juvenile survival, inadequate flows for moving juveniles out of the system quickly, and reductions in water quality due to inputs of

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manufactured and naturally occurring chemicals resulting primarily from agricultural practices. Many of these conditions are exacerbated during drought years when little water is available for attraction flows, flushing flows, or pollution dilution.

3. Survival of outmigrants.

Survival of outmigrating smolts is affected by present conditions in a number of ways. The altered flow conditions below dams have favored some predatory fishes, such as smallmouth bass (*Micropterus dolomieu*), that prey on smolts during outmigration (EAEST 1992). Entrainment of smolts by small agricultural diversions within the Delta is probably a factor, though probably minor. Operation of the SWP and CVP pumps are likely a more important factor, especially when San Joaquin River outflows are low. Smolt losses include direct entrainment and alterations in hydrologic conditions that cause diversions of smolts from normal outmigration and prolong the outmigration period. The diverted smolts are exposed to Delta mortality factors such as predation for a longer period. Studies of outmigrant survival indicate that more than 80% of San Joaquin salmon smolts die while migrating from the three rivers through the San Joaquin River and the Delta (CDFG 1991). It is difficult to assess indirect effects of the pumps which may be six times greater than direct effects, but at least 38-47 percent of the smolt mortality is associated with CVP and SWP pumps in the south Delta (EAEST 1992).

4. Harvest.

When populations are large, harvest likely does not have a major effect on San Joaquin fall chinook. However, at the present low population levels the loss of even a small number of fish can represent a major portion of returning adults. One major problem is that the San Joaquin fall chinook mix with Sacramento fall chinook in the ocean; therefore, there is no way to limit harvest of San Joaquin chinook without reducing harvest of the larger Sacramento River stocks. In any case, the rate of ocean harvesting increased steadily since the early 1940s (Reisenbichler 1986), although restrictions on ocean harvest are now in place. Poaching may also have a major effect when populations are small, especially when poaching occurs on the few adults that actually reach the spawning grounds.

5. Hatcheries.

At present there is only one salmon hatchery in the San Joaquin drainage, the Merced River Fish Facility operated by CDFG. Fish are raised at the Merced River Fish Facility and released at various points in the drainage. Only eggs collected from within the basin are used. Coded wire tagged Merced hatchery fish sometimes make up a significant portion of adult escapement. In 1990, 110 of the estimated 941 adults returning to the basin originated from the hatchery (CDFG 1992b). No comparisons of the genetics of hatchery and naturally spawning fish have been conducted so it is unknown if differences exist. Low numbers of Sacramento basin fish are routinely recovered from San Joaquin Basin streams. For example in 1990, five fish from Sacramento hatcheries were recovered (CDFG 1992b).

6. Water quality.

There is no strong evidence that pesticides or other substances resulting from agriculture or other human activities have a detrimental effect on salmon during outmigration. Saiki *et al.* (1992) demonstrated that agricultural drainage water could cause mortality and reduced growth of chinook salmon in laboratory bioassays. However, detrimental effects only occurred at high concentrations of drainwater and it is unknown if such effects are important at the low concentrations smolts experience during outmigration. The detrimental effects observed were attributed primarily to high concentrations of some ions, particularly sulfate, in ratios atypical of surface waters.

Poor water quality (high temperatures, high salinities, low dissolved oxygen) in the San Joaquin River and Delta may also delay the movement of adult fish into their spawning grounds or cause direct

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mortality. Adult females exposed to stressful environmental conditions, especially temperatures greater than 17°C, may have reduced survival of their eggs (Marine 1992).

Conservation measures: There is longstanding interest in improving runs of San Joaquin fall chinook. Attempts to improve populations have included testing of an electrical fish barrier and a physical barrier upstream of the confluence of the Merced River to prevent straying of adult fish, construction and rehabilitation of spawning riffles, construction of a temporary barrier at Old River to prevent entrainment of outmigrating smolts, and when possible, coordination of water releases to provide attraction or outmigration flows. These efforts have been funded by a wide range of Federal, State and private agencies.

For the Tuolumne River, reauthorization of New Don Pedro Dam by the Federal Energy Regulatory Commission will result in improved conditions for spawning fall-run chinook salmon and for their early life history stages. The exact nature of improvements are not yet decided, but interim standards established by CDFG have resulted in extra water being released to benefit the salmon (T. Ford, Turlock Irrigation District, personal communication). Interim releases, however, are significantly below those deemed necessary by the Service to restore the Tuolumne River ecosystem (M. Thabault, USFWS, personal communication). Releases to benefit salmon are also being negotiated for the Merced River.

The State Water Resources Control Board's Draft Decision 1630 recognized many measures that have been suggested for recovering San Joaquin fall chinook including operational changes at CVP and SWP pumps to create net downstream flow during outmigration, pulse flows, improved screening, and an upper Old River barrier. The upper Old River barrier will only be used in a coordinated approach with lowered exports and increased flows to limit its negative effects on delta smelt and winter-run salmon. The Central Valley Project Improvement Act (Miller-Bradley Bill of 1992) makes protection of fish one of the goals of the CVP and calls for a doubling of anadromous fish populations. Presumably some of the water dedicated to this purpose will be used to enhance San Joaquin fall chinook. The proposed USEPA water quality standards for the Sacramento-San Joaquin estuary include smolt survival objectives for San Joaquin fall chinook.

RESTORATION

Restoration objective

The objective of this portion of the Delta Native Fishes Recovery plan is to restore naturally spawning San Joaquin fall-run chinook salmon to the optimal numbers that can be supported by spawning and rearing habitat available in the Stanislaus, Tuolumne, and Merced rivers by improving smolt survival through the Delta. The goal is to restore survival rates of outmigrating smolts to levels that existed before the construction of the CVP and SWP pumps in the south Delta, because conditions in the Sacramento-San Joaquin estuary must not be an obstacle to the restoration of the salmon after restoration measures are in place upstream and in the ocean fishery. If flows are provided to the San Joaquin River below Friant, then the objective numbers should be increased. The measures taken to protect migrating adult and juvenile San Joaquin fall chinook should be balanced against measures required to meet the environmental needs of other native fishes of the Delta, including other runs of chinook salmon.

Restoration criteria

San Joaquin fall-run chinook salmon will be regarded as restored when (1) the number of naturally spawning fish in the Stanislaus, Tuolumne, and Merced rivers reaches a median number of

20,000 fish and the three-year running average does not drop below 3,000 fish, for 15 years, three of which are dry or critical years and (2) when the smolt survival rates approach pre-project levels when adult numbers decline to less than 3,000 naturally spawning fish. The number of spawners can be estimated by carcass and redd counts. A model has been developed for estimating smolt survival through the Delta. The smolt survival index is a calculated variable (USFWS 1992), based on on-going tagging studies, that is presumed to have a strong positive relationship to actual smolt survival rates. The model relies on the relationship between salmon smolt survival and flows in the San Joaquin River, rates of diversion into Old River, and export rates at the CVP and SWP pumps. The model to set smolt survival criteria (USFWS 1992) was considered, but rejected due to lack of sufficient precision to set specific criteria. A revised model incorporating more data is now available and should be considered (P. Brandis, USFWS, personal communication). These restoration goals can be achieved only if there is simultaneously improvement in conditions in the spawning and rearing streams, improvement in conditions in the lower San Joaquin River and in the Delta, and improved management of the fishery to allow for increased survivorship of adults during periods of low population size. Salmon taken by hatcheries for artificial spawning will not be counted toward meeting criteria.

Number of spawners: The criterion for number of spawners is composed of two parts, a median population size and a minimum population size. A median population size of 20,000 spawning fall chinook salmon should be maintained in the Stanislaus, Tuolumne, and Merced rivers combined. This 20,000 figure is based on two independent estimates of the optimal number of spawners based on stock-recruit relationships (Reisenbichler 1986; EAEST 1992). This population size assumes an equal (or nearly equal) sex ratio and that 90% or more of the females are age 3 or older. It does not include fish taken by hatcheries for artificial spawning.

The minimum population size is based on an analysis of the three-year running average of San Joaquin fall chinook for the period 1951-1972. This period was chosen because any contribution from pre-Friant Dam San Joaquin River fish is excluded and it only includes years when pumping rates at the SWP were absent or low and presumably had minimal influence on the populations. The minimum three-year running average during this period was 1,143 fish, but this included the 1961-1963 period which includes the two lowest counts in the period of record. Excluding these two years and treating the remaining years as a continuous data set gave a minimum running average of 4,560 fish. An intermediate value of 3,000 fish was selected as appropriate because it allows for significant variability in population size while protecting against extremely low population levels that have been associated with droughts under past and present conditions. Within the period 1951 to 1993, the population has only failed to meet a minimum three-year running average of 3,000 spawners during the periods 1963-1964, 1978-1980, and 1991-1993. All of these periods are associated with drought conditions in the drainage. The 3,000 number is achievable because of greater assurance of instream flows through regulatory processes.

Both the median and minimum population levels must be met for a period of 15 consecutive years for restoration. This period represents five generations of a three-year life cycle. The choice of five generations is consistent with the other species included in this and other recovery plans. Three of the 15 years must be dry or critical years to insure that the population can withstand stressful conditions. Failure to meet the minimum population level in any year will result in the start of a new 15-year evaluation period. The median level can be met in any period of 15 consecutive years.

Smolt survival index: The principal means for measuring the suitability of habitat conditions for juvenile San Joaquin fall chinook in the Delta is to have smolt survival rates be equivalent to what they were prior to the closure of Friant Dam and the present configuration of the CVP and SWP (i.e., 1940s level of development). Accurately measuring smolt survival rates is extremely difficult, so it is not recommended as absolute criterion for restoration until the present model (USFWS 1992) is refined or more accurate models are developed (activities which are underway). Until reliable measures of smolt survival are available, the criteria for number of spawners will have precedence. When reliable survival criteria are developed, they should be used primarily in conjunction with the adult criteria. A drop in adult numbers to below 3,000 fish in any year should require higher smolt survival rates (near 1940s level) than permitted when adult numbers are higher. Such action should help avoid failure to meet the minimum three-year running average criterion of 3,000 naturally spawning fish. A schedule of minimum survival rates based on adult numbers should be developed if possible.

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Table 8.1. Estimates of number of San Joaquin fall chinook returning to streams in the San Joaquin River drainage (adapted from SJVDP 1990a). The total is simply the sum of the reported values and does not make any adjustments for the level of certainty associated with an estimate.

Year	San Joaquin River	Merced River	Tuolumne River	Stanislaus River	Total
1940	-	1,000	122,000	3,000	126,000
1941	-	1,000	27,000	1,000	29,000
1942	-	-	44,000	-	44,000
1943	-	-	35,000	-	35,000
1944	5,000	-	130,000	-	135,000
1945	56,000	-	-	-	56,000
1946	30,000	-	61,000	-	91,000
1947	6,000	-	50,000	13,000	69,000
1948	2,000	-	40,000	15,000	57,000
1949	-	-	30,000	8,000	38,000
1950	0	-	-	-	0
1951	0	-	3,000	4,000	7,000
1952	0	-	10,000	10,000	20,000
1953	0	<500	45,000	35,000	80,500
1954	0	4,000	40,000	22,000	66,000
1955	0	-	20,000	7,000	27,000
1956	0	0	6,000	5,000	11,000
1957	0	400	8,000	4,000	12,400
1958	0	500	32,000	6,000	38,500
1959	0	400	46,000	4,000	50,400
1960	0	400	45,000	8,000	53,400
1961	0	50	500	2,000	2,550
1962	0	60	200	300	560
1963	0	20	100	200	320
1964	0	40	2,000	4,000	6,040
1965	0	90	3,000	2,000	5,090

Year	San Joaquin River	Merced River	Tuolumne River	Stanislaus River	Total
1966	0	40	5,000	3,000	8,040
1967	0	600	7,000	12,000	19,600
1968	0	500	9,000	6,000	15,500
1969	0	600	32,000	12,000	46,600
1970	0	5,000	18,000	9,000	32,000
1971	0	4,000	22,000	14,000	40,000
1972	0	3,000	5,000	4,000	12,000
1973	0	1,100	2,000	1,200	4,300
1974	0	2,000	1,100	800	3,900
1975	0	2,400	1,600	1,200	5,200
1976	0	1,900	1,700	600	4,200
1977	0	400	400	0	800
1978	0	600	1,300	50	1,950
1979	0	2,100	1,200	100	3,400
1980	0	2,800	500	100	3,400
1981	0	10,400	14,300	1,000	25,700
1982	0	3,000	7,000	-	10,000
1983	0	18,200	14,800	500	33,500
1984	0	34,000	13,700	12,000	49,700
1985	0	16,100	40,300	13,300	69,700
1986	0	6,200	7,300	5,900	19,400
1987	0	3,900	14,800	6,300	25,000
1988[1]	2,300[2]	3,200	6,300	12,300	24,100
1989	322[2]	211	1,274	1,543	3,028
1990	280[2]	73	96	492	941
1991	200[2]	119	77	321	717
1992	0[3]	978	132	267	1,377
1993	0[3]	1,765	475	367	2,607

[1] Estimates for 1988 to 1990 from CDFG (1992b) and from 1991 to 1993 from C. Mayott, CDFG, personal communication. Estimates for 1993 are preliminary estimates only.

[2] Estimates of stray fish entering stream channels upstream of the confluence of the Merced River.

[3] In 1992 an electrical barrier was in place and in 1993 a physical barrier was in place (T. Ford, Turlock Irrigation District, personal communication)

9. SACRAMENTO PERCH

Archoplites interruptus (Girard)

Introduction

Status: Sacramento perch are believed to be extirpated from the Delta at this time. Moyle et al. (1993) recommend that it be listed as species of special concern by CDFG.

Restoration potential: The Sacramento perch is under a high degree of threat and has low restoration potential.

Description: The Sacramento perch has more spines (12 to 13) in the dorsal fin than any other centrarchid. It is fairly deep bodied (depth goes 2-1/2 times into standard length) with a large oblique mouth, the maxillary reaching to about the middle of the eye. The spinous portion of the dorsal is continuous with the soft-rayed portion (10 rays). The anal fin has 6 to 7 spines and 10 rays. There are 38 to 48 scales along the lateral line, 25 to 30 long gill rakers, and numerous small teeth on the jaws, tongue, and roof of the mouth. The overall color tends towards brown, with 6 to 7 irregular, dark vertical bars on the sides, black spots on the operculae, and a white belly. Live fish tend to have a metallic green to purple sheen on the sides.

Taxonomic Relationships: Sacramento perch is the only member of the centrarchid family that occurs naturally west of the Rocky Mountains and is believed to have been isolated since the Miocene period (Miller 1958). Due to its isolation and lack of competition from closely related species, it has retained many ancestral structural and behavioral characteristics (Moyle 1976). It is a monotypic genus, reflecting its distinctiveness from other members of the family.

Distribution: Although originally widely distributed in the Sacramento, San Joaquin, Pajaro, and Salinas rivers, and Clear Lake, Lake County, today Sacramento perch are found only in scattered localities in California, principally farm ponds and reservoirs into which they have been introduced. The population in the Russian River is presumably also derived from introductions. Large populations have become established in San Luis Reservoir, Merced County, Clear Lake Reservoir, Modoc County, Crowley Lake, Inyo County, Lake Almanor, Plumas County, and Blue Lake, Lake County. They were introduced into Nevada, probably in 1877, and are now abundant in Pyramid and Walter lakes, as well as in other localities (La Rivers 1962). Since then, they have been successfully planted in alkaline lakes in Utah, Colorado, Nebraska, North Dakota, and South Dakota (McCarraher and Gregory 1970). Almost all recently established populations are derived from the population that is now extinct in Brickyard Pond (Greenhaven Lake), Sacramento (D. Vanicek, Sacramento State University, personal communication).

Habitat Requirements: Originally, Sacramento perch were inhabitants of sloughs, sluggish rivers, and lakes of the Central Valley floor. Perhaps the most important characteristic of their habitat was the presence of beds of rooted and emergent aquatic vegetation, which served as spawning grounds and as nursery areas for young fish. Since the quality of the waters they lived in tended to fluctuate with floods and droughts, Sacramento perch evolved the ability to withstand high turbidities, high temperatures, and high salinities and alkalinities. McCarraher and Gregory (1970) found that they could survive and reproduce in chloride-sulfate waters with salinities up to 17,000 ppm and in sodium-potassium carbonate waters with total alkalinities of over 800 ppm. These waters exclude most other fish species.

Life History: Growth rates are variable and are affected by both biotic and abiotic factors. The diets of sunfishes (*Lepomis* spp.) and Sacramento perch are often very similar in California, but Sacramento perch generally grow faster and larger than the sunfishes. Age I fish are usually 7 to 15 cm TL, Age II are 10 to 19 cm TL, Age III are 13 to 24 cm TL, and Age IV are 18 to 28 cm TL. (McCarraher and Gregory 1970). Nine-year-old fish from Pyramid Lake range in size from 35 to 42 cm TL (Mathews 1962). These seem to be the largest and oldest fish recorded in recent years although Jordan and Evermann (1896) gave a maximum length of 61 cm and La Rivers (1962) mentioned a 3.6 kg perch from Walker Lake, Nevada. As in most fish, growth in older individuals is mostly in weight rather than in length. Thus, a 10 cm TL perch from Pyramid Lake weighed about 15 gm, a 20 cm perch, 150 gm, a 30 cm perch, 550 gm, and a 40 cm perch, 1200 gm (Mathews 1962). Overcrowding, diet, and the sex of the fish will affect the growth rate. Stunted populations can occur in underharvested farm ponds. Populations of large, fast-growing fish occur in lakes where the adults are primarily piscivorous. Mathews found that females grow faster and have lower mortality rates than males, so that large perch tend to be predominately females.

Sacramento perch breed for the first time during their second or third summer of life. The fecundity of females is higher than that of most centrarchids but varies with the size of the fish. Mathews (1962) found the number of eggs in sixteen females 120 to 157 mm TL from Lake Anza, Contra Costa County, to range from 8,370 to 16, 210 with a mean of 11,438; sixteen females 196 to 337 mm TL from Pyramid Lake contained from 9,666 to 124,720 eggs. Spawning occurs in California from the end of March to the beginning of August, although late May and early June are generally the peak times. Water temperatures usually have to be between 21° and 29° C for spawning (McCarraher and Gregory 1970). Unlike introduced sunfishes, Sacramento perch, except when breeding, show little intraspecific aggressive behavior when kept in aquaria or small ponds. They also do not school strongly, although they will congregate in favorable localities, especially for breeding. Young-of-the-year fish either remain among aquatic plants or congregate in shallow water.

Abundance: Sacramento perch today are probably as abundant in other western states as they are in California, thanks to their ability to live in alkaline waters that will not support other sport fishes (McCarraher and Gregory 1970). Their decline in California was rapid. Rutter (1908) found that they were rare in his 1898-1899 survey of Central Valley fishes, although he also noted that they were taken in "marketable quantities" in the Delta region. Between 1888 and 1899, 40,000 to 432,000 pounds were sold annually in San Francisco (Skinner 1962). By 1966, Sacramento perch were rare in the Delta (Turner 1966). In 1992, a 15 cm Sacramento perch was captured in the Delta, but it unlikely that an established population exists there. In Clear Lake, Lake County, they have declined steadily since the 1930 fish survey which found them still abundant. By the late 1940s their numbers were greatly reduced, but they were still common enough for Murphy (1948) to observe spawning in the lake. In 1961, an exhaustive fish-sampling program in the lake turned up only nine adult Sacramento perch and no juveniles (Cook and Conners 1966). More recent surveys have turned up only occasional individuals.

Reasons for decline: Three hypotheses have been advanced to explain the decline of Sacramento perch: habitat destruction, egg predation, and interspecific competition. Habitat destruction, especially the draining of lakes and sloughs and reduction of aquatic weedbeds needed for spawning, is the hypothesis favored by Rutter (1908) and Mathews (1962). However, the fact that Sacramento perch declined in areas where suitable habitat still exists (e.g., Clear Lake, sloughs of the Delta) makes it unlikely that this is the only reason, although it has been a contributing factor.

Egg predation, especially by catfish and carp, as the cause of decline was first advanced by Jordan and Evermann (1896) and was supported by the observations of Murphy (1948) that Sacramento perch did not defend their spawning sites. However, observations of Mathews (1965) that they in fact do defend the sites against potential egg predators tends to make egg predation unlikely as a primary cause of the decline.

Interspecific competition for food and space may be the single most important cause of the decline since, almost invariably, local declines of Sacramento perch populations have been associated with increases in numbers of introduced centrarchids, especially bluegill. In aquaria and small ponds, bluegill and green sunfish dominate Sacramento perch, chasing them away from favored places. Such behavior in the wild could force young fish out of shallow weedy areas and into more exposed waters where they would be more vulnerable to predation and have less food available to them. Bluegill could similarly keep Sacramento perch away from spawning areas even though bluegill build nests in the clearings rather that in the vegetation itself. The importance of interspecific competition is also reflected in the fact that Sacramento perch today are successful mostly in relatively simple fish communities where they can occupy the position of top littoral carnivore.

The decline is probably due to all three factors working together, since habitat alteration and fish introductions have occurred simultaneously throughout the Central Valley. No Sacramento perch, no matter how aggressive, is likely to be able to defend its spawning area against a determined school of egg-eating bluegill or large carp. Thus, consistent defeats in interspecific encounters, especially of young fish, may serve to accelerate a decline started by other factors.

Conservation measures: To halt the general downward trend in California Sacramento perch populations, the California Department of Fish and Game tried to establish them in Central Valley farm ponds (Fisk 1972). However, their tendencies to die out when other centrarchid species are introduced, to overpopulate and become stunted when left by themselves, and to be difficult to catch with standard centrarchid fishing techniques have not made this task easy. Such efforts should nevertheless be continued and experiments should be run to determine what other fish species can be stocked with Sacramento perch to provide maximum growth and prevent stunting. Sacramento perch are worth developing as a gamefish not only because they are native Californians but also because they are scrappy fighters, grow rapidly in the Central Valley climate, and can achieve larger sizes than introduced sunfishes, their main rivals.

RESTORATION

Objective

The objective of this part of the Delta Native Fishes Recovery Plan is to investigate the possibility of restoring Sacramento perch to the Delta ecosystem.

10. RECOVERY ACTIONS

Introduction

Implementation of the recovery tasks outlined in this section are needed to achieve the species' recovery objectives specified above. Management actions in the narrative outline were selected on the basis of biological benefits and ability to implement. Potential actions with uncertain or low biological benefit and those with substantial feasibility constraints were considered but not included as necessary components of the recovery program for the Delta. Feasibility constraints included costs, likelihood of action being done, enforcement, and permitting problems.

Definitions and abbreviations

Priorities in parentheses in the following stepdown narrative are assigned as follows:

1. **Priority 1** - An action that <u>must</u> be taken to prevent extinction or to prevent the species from declining irreversibly in the <u>foreseeable</u> future.

2. **Priority 2** - An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

3. **Priority 3** - All other actions necessary to meet the recovery objective.

<u>Key to abbreviations used in Stepdown Narrative and Implementation Schedule</u>:

ACE - U. S. Army Corps of Engineers
CCWD - Contra Costa Water District
CVP - Central Valley Project
DFG - California Department of Fish and Game
FERC - Federal Energy Regulatory Commission
FWS - U. S. Fish and Wildlife Service
NMFS - National Marine Fisheries Service
PG and E - Pacific Gas and Electric Company
Private - Private water rights holders
SWP - State Water Project
SWRCB - State Water Resources Control Board
USEPA - United States Environmental Protection Agency
USCG - U. S. Coast Guard
USDA - U. S. Department of Agriculture

NARRATIVE OUTLINE FOR RECOVERY OF DELTA NATIVE FISHES IN THE SACRAMENTO-SAN JOAQUIN DELTA

1 Enhance/restore aquatic and wetland habitat.

Recovery of listed species in the Sacramento-San Joaquin Delta will require an integrated program to reestablish spawning habitat, migration corridors, and rearing areas in upstream areas, the Delta, and Suisun Bay and Marsh. The Delta has been profoundly altered by human activity (Cross and Williams 1981). This alteration began with hydraulic gold mining operations in the 1800s that led to downstream deposition of sediments in the estuary. At about the same time, dredging and levee building within the Delta changed existing tidal marsh into a series of islands separated by rivers and sloughs. In more recent times, the additional effects of dam construction, the diversion of Delta water, and other human-induced alterations have resulted in extinction of thick-tail chub and San Joaquin spring-run salmon and extirpation of Sacramento perch. These changes have also caused declines in other native fish through changes to migration routes, destruction of shallow-water habitat, reduced Delta inflows and outflows, and entrainment. Active management for the foreseeable future will be required to enhance and restore aquatic habitat to reverse declines of native fish and recover numbers and distributions to historical levels.

11 Improve in-Delta and downstream of Delta habitat conditions.

Habitat within the Delta is used by fish for spawning and rearing and as an upper estuary migration corridor by anadromous fish. Habitat downstream of the Delta is used as a downstream migration corridor to the bays and ocean by anadromous fish, and as a rearing area for many native fish.

111 Increase freshwater flows.

Freshwater flows passing through the Delta improve in-Delta habitat, provide transport and attractant flows for anadromous and native fishes, and produce outflows that mix with saltwater and provide suitable rearing habitat in Suisun Bay. Existing water storage and delivery systems constrain the ability to increase flows above current levels. As water contracts, licenses, and water rights expire or are renewed, an opportunity exists to modify provisions to benefit Delta fishes. Many of these renewal processes are subject to consultation under section 7 of the Endangered Species Act, which will assist Federal agencies in carrying out programs for the conservation (recovery) of listed species.

1111 Increase Delta inflows to improve the quality and availability of habitat within the Delta (priority 3).

Past operations of the water projects as well as other water diversions have decreased Delta inflows at critical times when habitat quality and availability is necessary for fish. The seven fishes of concern benefit from increases to Delta inflows between October 1 and July 31. Table 9.1 shows the specific time periods when Delta inflows should be provided to benefit these fish.

1112 Provide transport inflows and outflows for larval and juvenile dispersal from the Sacramento River (priority 1).

Historically, storm events and run-off from snowmelt provided transport flows that moved larval and juvenile fish to downstream rearing areas and outmigrating anadromous fish to the ocean. These transport flows were short-term pulse flows or of longer duration. Through damming of rivers and diversion of flows, these transport flows have been diminished. Additionally, spring-run chinook salmon need flows from Sacramento River tributaries to transport smolts to the ocean. Figure 10.1 shows the time intervals when transport flows should be provided for the seven fish species.

1113 Provide transport inflows and outflows for larval and juvenile dispersal from the San Joaquin River (priority 1).

Several of the resident native Delta fish spawn on the San Joaquin River side. Additionally, San Joaquin fall-run salmon need flows to move outmigrating smolts to the ocean.

1114 Increase Delta outflows to improve the quality and availability of habitat within Suisun Bay.

Suisun Bay is used as a rearing area for several native Delta fish. Suitable placement of the 2 ppt isohaline is key to providing adequate shallow water habitat for these fish. Placing the isohaline at three areas for varying amounts of time will mimic historic hydrologic variability and provide rearing benefits for native Delta fish. The number of days for placement of the isohaline at each location will depend the amount of precipitation within the year. In wet years, more days will be required at the most downstream point, Roe Island. In dry years, the isohaline will be placed for more days at the upstream points, the confluence and Chipps Island.

11141 Placement of the 2 ppt isohaline at Roe Island (priority 1).

The placement of the 2 ppt isohaline at Roe Island would have large benefits for longfin smelt and delta smelt and also would benefit Sacramento splittail. These benefits come from the wide geographic area at Roe Island where shallow water habitat can be found and the strength of the entrapment zone and resulting productivity is high.

11142 Placement of the 2 ppt isohaline at Chipps Island (priority 1).

Placement of the 2 ppt isohaline at Chipps Island would have large benefit to delta smelt and Sacramento splittail. These benefits would be the same as placement at Roe Island but to a lesser extent.

11143 Placement of the 2 ppt isohaline at the confluence of the Sacramento-San Joaquin River at Collinsville (priority 1).

Placement of the 2 ppt isohaline at the confluence of the Sacramento-San Joaquin River at Collinsville would have some benefits to rearing delta smelt and Sacramento splittail. These benefits would be less than placement at Roe Island or Chipps Island because of decrease in strength of entrapment zone and shallow water habitat plus tidal movement that would place rearing fish within the zone of influence of the CVP and SWP pumps about 50 percent of the time.

112 Develop additional shallow-water habitat, riparian vegetation zones, and tidal marsh.

Diking and dredging of marshes, islands, sloughs, and river channels in the Delta and Suisun Bay have resulted in decreases in shallow-water habitat, intertidal fresh and brackish marshes, and riparian vegetation zones. These decreases have simplified habitat structure, eliminated cover from predators, curtailed spawning and rearing habitat and reduced productivity. It is anticipated that restoring shallow habitats will help to reduce the declines.

1121 Develop additional habitat and vegetation zones within the Delta (priority 2).

The Delta provides habitat for spawning adults and a migration corridor for upstream and downstream migrants. Providing additional shallow-water habitat and vegetation zones can be expected to increase the availability of spawning areas and increase the general productivity. The following spawning and rearing areas should be considered for restoration as shallow-water, vegetated habitat: Prospect Island, Hastings Tract, Liberty Island, New Hope Tract, Brack Tract, and Terminous Tract. Studies need to be conducted to examine the feasibility of restoring these areas and to identify additional sites.

1122 Develop additional shallow-water habitat and vegetation zones within Suisun Marsh and Suisun Bay.

Suisun Bay and Suisun Marsh are areas where native fish spawn and rear. These areas also provide a corridor for upstream and downstream migration. The development of additional shallow-water habitat and vegetation zones should increase the availability and productivity of these areas. In Suisun Marsh, these areas should include fresh and brackish water habitat for spawning delta smelt, longfin smelt, and Sacramento splittail and tidal areas for larval and juvenile fish to rear.

11221 Restore additional shallow-water spawning habitat in upstream freshwater areas (priority 2).

Additional shallow-water habitat in upstream areas should be restored to provide spawning habitat for delta smelt, longfin smelt, and Sacramento splittail. These areas include Joice Island, Hill Slough, Cutoff Slough, First Mallard Slough, northern Suisun Slough, and Nurse Slough.

11222 Restore additional shallow-water rearing habitat in tidal areas (priority 2).

Additional shallow-water habitat in tidal areas should be restored to provide rearing habitat for delta smelt, longfin smelt, and Sacramento splittail. These areas should include habitat north of Grizzly Bay on Grizzly Island.

12 Reduce entrainment losses to water diversions.

Entrainment losses resulting from water diversions is an important cause of decline of native fishes in the Delta. Federal, State and private diversions, and more than 1,800 agricultural diversions entrain eggs, larvae, juvenile and adult native fishes. In many cases, entrainment results in losses of fish, either due to immediate mortality or due to removal from Delta habitat. Active management for the foreseeable future is anticipated to reduce effects of entrainment and reverse the decline of native fish.

121 Change operations at public facilities to reduce losses.

Federal, State and municipal facilities have some of the largest effects on entrainment losses of native delta fishes. These facilities may be managed in ways that decrease losses and thus may reverse the decline of these fish.

1211 Restrict CVP and SWP Pumping Plant diversions from the Delta.

The CVP and SWP Pumping Plants have a "zone of influence" that includes much of the Delta. Restriction of these diversions will decrease losses of native delta fish. These restrictions will act in concert with transport flows to lessen the effects of entrainment. Figure 10.1 shows the time intervals when restrictions on CVP and SWP pumping would benefit the seven species.

12111 Provide flows and restrict pumping (priority 1).

A combination of flows and pumping restrictions should be used to transport larval fish spawned in the Delta to suitable rearing habitat in Suisun Bay.

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12112 Provide transport flows to protect Sacramento River salmon smolts (priority 1).

Salmon smolts on the Sacramento River should be protected during their outmigration through the Delta to the ocean..

12113 Provide transport flows to protect salmon smolts on the San Joaquin River (priority 1).

San Joaquin River outmigrating salmon smolts should be protected through use of an appropriate San Joaquin salmon model to restrict pumping and provide flows in March through May.

1212 Improve fish handling and salvage at the CVP and SWP Fish Facilities.

Entrainment losses due to CVP and SWP Pumping Plants were recognized as a problem shortly after construction of the Federal plant. A Federal fish salvage facility was constructed in the early 1950s, and a State Fish Facility was constructed concurrent with construction of the SWP Pumping Plant in the late 1960s. These fish salvage facilities are not 100 percent effective in reducing losses of fish. However, new procedures that improve fish handling and salvage are anticipated to reduce losses of some native fish species.

12121 Change operations of facilities to reduce losses and facilitate fish movement within the Delta (priority 3).

Several changes to operation of the facilities are anticipated to reduce losses of native delta fish. These changes include optimizing salinity in transport tank water, shorter residence time in holding tanks, and other proposed changes to physical structures in the facilities. Location of Delta release-points for fish need to be changed to facilitate upstream or downstream movement. This would be determined seasonally, and by presence of various life-stages within the salvage.

12122 Remove green sturgeon from Clifton Court Forebay and transport to downstream area (priority 3).

Green sturgeon have been found in Clifton Court Forebay where they are unable to leave and do not have suitable habitat for spawning or rearing of young. Trapping and downstream transport of fish to Suisun Bay would return fish to a more suitable area.

1213 Reduce predation within the State's Clifton Court Forebay and within other CVP and SWP diversions (priority 2).

Predatory fish, including striped bass, have been found to accumulate at high numbers in Clifton Court forebay.

1214 Screen diversions at the CCWD Rock Slough intake (priority 2).

Recent monitoring of Rock Slough has demonstrated the presence of listed and non-listed species of native Delta fishes that would be susceptible to entrainment by CCWD intake. Screening this diversion would reduce losses of some life-stages of fish entrained at this intake.

1215 Restrict diversions by the CCWD when eggs, larvae, or juveniles are present using generalized "windows" or recent-time monitoring (priority 3).

Eggs, larvae, and juvenile fish are found near Contra Costa Water District's intakes. Entrainment losses of these life-stages are not easily reduced through screening. Restricting diversions to times when these life-stages are not present would reduce entrainment losses. Recent-time monitoring determines presence of eggs, larvae, and juvenile fish. This technique provides accurate and efficient means of restricting diversions during only those periods when critical life-stages are detected. Figure 10.1 shows "windows" when sensitive life-stages of the seven fish species are present. These "windows" could be used to restrict diversions to reduce losses.

1216 Restrict diversions to the North Bay Aqueduct when eggs, larvae, or juveniles are present using generalized "windows" or recent-time monitoring (priority 3).

Eggs, larvae, and juvenile native Delta fish have been found in the Barker and Cache Slough area where the North Bay Aqueduct is located. Since screening of this intake is not adequate to reduce losses of these critical life-stages, diversions need to be restricted.

1217 Evaluate diversion of San Joaquin salmon from their migratory route at Old River and other strategic locations (priority 2).

Past operation of CVP and SWP Pumping Plants has resulted in entrainment of San Joaquin fall-run juveniles and straying of adults. Placement of a structural barrier or operational methods may reduce entrainment and straying of salmon.

1218 Close Delta Cross Channel gates when juveniles are present using generalized "windows" or recent-time monitoring (priority 2).

The Delta Cross Channel is a hydraulic connection between the Sacramento River and the central Delta that was built to provide higher quality water to the CVP and SWP Pumping Plants. Closure of the Delta Cross Channel gates has been found to reduce straying of fish into the central Delta where entrainment losses at the CVP and SWP Pumping Plants and agricultural diversions are higher. Timing of these closures should reflect intervals when critical life-stages are present.

1219 Reduce movement of fish into Georgiana Slough.

Georgiana Slough is a natural waterway that connects the Sacramento River with the central Delta. Migrating fish that stray into the central Delta are more susceptible to entrainment losses due to agricultural diversions and CVP and SWP Pumping Plants. Reducing movement of fish into Georgiana Slough is anticipated to decrease these entrainment losses. Two experimental technologies currently are being evaluated to reduce this movement.

12191 Evaluate reduction of fish movement into Georgiana Slough through use of hydroacoustic barrier or deflector (priority 2).

Various forms of physical barriers have been suggested to deflect fish away from the entrance to Georgiana Slough. Deflectors would partially block the entrance to the Slough but would not impede water flow. The hydroacoustic barrier is an experimental device that currently is being tested on chinook salmon to startle fish away from Georgiana Slough. If these devices are successful, straying of fish into the central Delta may be diminished, thus reducing entrainment losses. Complete testing would be necessary to determine the effectiveness in reducing straying and determining any negative effects to water quality or central Delta hydrology.

122 Change operations at private facilities to reduce losses.

A large secondary source of native Delta fish entrainment and impingement losses results from private diversions in the Delta and Suisun Bay. Larval and juvenile fish rear in Suisun Bay throughout most of the year so that the potential for losses of critical life-stages is high at large screened diversions such as the Pacific Gas and Electric power plant intakes. More than 1,800 unscreened agricultural diversions scattered throughout the Delta divert all life-stages of fish.

1221 Reduce entrainment and impingement losses at the PG and E Pittsburg and Contra Costa power plants and other industrial diverters when eggs, larvae, or juveniles are present (priority 2).

Because existing screens are not effective in decreasing entrainment a seasonal window or recent-time monitoring program is needed to reduce ongoing losses.

1222 Reduce entrainment at agricultural diversions.

The large numbers of unscreened agricultural diversions throughout the Delta cause large entrainment losses of all life-stages of Delta native fishes. Each of these diversions is unique and requires different approaches to reduce losses. Experimental studies are needed to determine effectiveness of different mechanical and operational solutions. Reducing these losses can be expected to help reverse the overall fish decline.

12221 Screen agricultural diversions in the Delta and tributaries (priority 3).

Most of the 1,800 agricultural diversions within the Delta and tributaries are currently unscreened. Screening these diversions would reduce entrainment of adult fish. Eggs, larvae, and juvenile fish would remain unprotected.

12222 Consolidate agricultural diversions in the Delta and tributaries (priority 3).

Some of the agricultural diversions within the Delta and tributaries could be consolidated to reduce entrainment losses of all life-stages of native Delta fish. The feasibility of combining diversions requires investigation.

12223 Restrict agricultural diversions when critical life-stages of fish are present (priority 3).

Eggs, larvae, and juvenile fish may not be protected through screening of intakes. Thus, entrainment losses of critical life-stages of native Delta fishes may only be substantially reduced through restriction of agricultural diversions. These restrictions may be implemented seasonally using a time schedule as shown in Figure 10.1 or through a recent-time monitoring trigger.

13 Reduce the effects of dredging.

Dredging destroys spawning habitat, mobilizes sediments containing toxic substances, blocks fish movement, and reduces the quality and quantity of shallow water habitat. Dredging continually occurs throughout the Delta and tributaries and in Suisun Bay and Suisun Marsh. The magnitude of the adverse effects of dredging are dependent on time of year and location within the Delta or Suisun Bay.

131 Require best management practices to minimize mobilization of sediments that might contain toxins.

Many of the sediments throughout the Delta and tributaries, and in Suisun Bay contain toxic substances. These toxic substances include mercury, tributytin, and selenium. Best management practices should be used to minimize the mobilization of these toxin laden sediments.

1311 Time dredging for periods when there is minimal tidal movement (priority 3).

Tidal action within an estuary is an important force in moving water and suspended particles. Tides vary in magnitude monthly and seasonally. Tidal direction varies twice daily, and moves the mixing zone upstream and downstream. Dredging should be timed to minimize the movement of contaminated sediments into areas containing critical life-stages of native Delta fish.

1312 Use silt curtains or suction dredges to localize sediment movement (priority 3).

Movement of sediments mobilized by dredging may be localized through use of silt curtains or suction dredges. These techniques should be used to minimize the effects of sediments on critical life-stages of native Delta fish.

133 No net loss of shallow-water (less than 3 meter deep) habitat and mitigate for all functions and values (priority 1).

Shallow-water habitat is critical for spawning, rearing, and refuge from predators for many native Delta fish. When shallow-water habitat is destroyed through dredging, it should be replaced so that there is no net loss of habitat less than 3 meters in depth. This mitigation ratio is anticipated to increase the amount of shallow-water habitat.

14 Reduce the effects of contaminants.

Toxins have an immediate lethal effect on various fish life-stages and a chronic effect that results in increased disease susceptibility, teratogenic effects, and behavioral effects. Toxins may become bound in sediments and released after years of residence time. Sources of toxic substances include agricultural drainage, and municipal and industrial by-products, and sewage.

141 Reduce input of contaminants from agricultural drainage.

Agricultural drainage contains insecticides, herbicides, fertilizers, and selenium. These toxic substances have the potential for acute and chronic effects on all life-stages of native Delta fish. Reduction of input of these substances is expected to reduce adverse effects on fish.

1411 Change application practices for insecticides, herbicides, and fertilizers (priority 2).

Levels of toxic substances in agricultural drainwater may be reduced through changes in application practices for pesticides and fertilizers. Timing, mode, and rates of application may be changed to reduce drainwater levels. Investigations are needed to determine efficacy of changes to current practices.

1412 Change residence times of insecticides, herbicides, and fertilizers (priority 2).

Residence times of pesticides and fertilizers may be altered through varying the compounds used (chemical breakdown), and irrigation practices that remove toxic substances. Investigations are needed to determine efficacy of changes to current practices.

1413 Retire agricultural lands where large quantities or concentrations of contaminants drain into the Delta (priority 2).

Some areas of the San Joaquin Valley have soils highly contaminated with selenium. Agricultural land retirement may be an effective means of reducing toxic drainwater entering the Delta and increasing Delta outflow. Land retirement may resolve these issues.

1414 Control point sources of toxic substances (priority 2).

Some drains seasonally have high levels of toxic substances. The Colusa drain is an oft-cited example of a point source containing high levels of diazinon, carbofuran, and molinate. Control of such point-sources may substantially reduce levels of contaminants that affect all life-stages of native Delta fish.

142 Reduce input of toxic substances from industrial discharges and municipal sewage treatment.

A source of contaminants into the Delta and Suisun Bay is industrial discharges and municipal sewage. Reducing these inputs should help recovery of native Delta fish by reducing acute and chronic effects and indirect effects on food organisms.

1421 Separate industrial from municipal sewage (priority 3).

Industrial sewage contains high levels of metals, organic and inorganic compounds that have specialized needs for disposal and treatment. Separation from municipal sewage allows these specialized disposal and treatment needs to be realized.

1422 Tertiary treat sewage (priority 3).

Toxic substances often are allowed to enter the Delta and tributaries and Suisun Bay without adequate treatment. Tertiary treatment of industrial discharges and municipal sewage will prevent these substances from having an adverse effect on native Delta fish.

143 Reduce input of toxic substances from urban non-point sources.

Urban use of pesticides, fertilizers, oil distillates and other toxic substances has led to high levels of these compounds in drainage water that spills untreated into the Delta and Suisun Bay. Although the magnitude of this problem is unknown, the potential adverse effects on native Delta species are high.

1431 Monitor and evaluate the magnitude of the problem (priority 2).

To assess the magnitude of the problem of urban non-point sources of toxic substances, a monitoring and evaluation program needs to be established.

1432 Educate public and private sectors on effects of toxic substances on fish and habitat, and on means of controlling input (priority 2).

Once the magnitude of the urban non-point sources of toxic substances is known, an outreach program needs to be developed to educate public and private sectors on the effects. A list of guidelines needs to be disseminated that allows the public and private sectors to change use patterns and disposal practices of these substances.

2 Reduce the effects of harvest (over-utilization).

With the decline of stocks of native Delta fishes, harvest for commercial or recreational purposes may be a significant source of added losses. Selective ways of minimizing the adverse effects of harvest is necessary for some of the native Delta fish.

21 Control and reduce recreational harvest of San Joaquin fall-run chinook salmon.

Recreational harvest of wild runs of fish in the San Joaquin River is a source of losses for fall-run chinook salmon. Controlling and reducing this harvest will help in recovering these fish.

211 Institute a selective fishery for San Joaquin River fall-run chinook salmon (priority 3).

Targeting and marking hatchery fish should be used to minimize adverse effects on wild fish. Use marked San Joaquin fall-run chinook salmon hatchery fish to take fishing pressure off wild fish.

212 Change angling regulations on the San Joaquin River (priority 3).

Angling regulations should be changed that allow only hatchery fish to be caught. This would allow wild chinook salmon to escape angling.

22 Halt all fisheries for green sturgeon until more is learned about the biology and abundance of the species.

Commercial and recreational harvest is the largest threat to green sturgeon. Recreational fishers do not distinguish between green and white sturgeon. Because green sturgeon are smaller than whites, slot limits designed to protect the largest white sturgeon spawners allow the largest reproductive green sturgeon to be taken.

221 Sportfishing for green sturgeon should be halted until species recovers (priority 2).

222 Anglers should be educated to distinguish between green and white sturgeon (priority 2).

Green sturgeon can be distinguished from white sturgeon by the presence of 1-2 scutes (bony plates) behind the dorsal and anal fins.

223 Initiate a program of tagging green sturgeon in the Sacramento River and estuary (priority 2).

A tagging program to see what contribution green sturgeon from the Delta make to the fisheries elsewhere, especially in Washington and Oregon, will provide needed information and determine exploitation rates. This would also answer the question as to whether or not the Sacramento River stock is distinct from other green sturgeon stocks.

23 Control and reduce illegal harvest (priority 2).

Harvest of listed species and fish caught at the wrong size or season should be reduced to minimize adverse effects to native Delta fish. This may be accomplished through increased enforcement. Funding and increases of personnel and equipment should be included as part of local project mitigation, fish licensing, and taxes.

24 Control and reduce commercial harvest.

Commercial harvest of wild runs of native Delta fish is another cause of the decline. Controlling and reducing this harvest should help the recovery of these species.

241 Institute a selective fishery (priority 2).

Targeting hatchery fish may limit adverse effects on Sacramento and San Joaquin River chinook salmon runs.

242 Change regulations (priority 1).

Regulations should be changed to eliminate harvest of green sturgeon and chinook salmon until runs are re-established.

25 Improve hatchery management.

Hatchery management can be improved so that fish stocks may be augmented to take fishing pressure off wild fish. This would allow wild stocks to recover. Hatchery production may be improved in a number of ways to allow additional stocking of fish. Improved propagation methodology and expansion of hatchery size will result in increased hatchery production. Reliance on hatcheries should be restricted, however, to applications that will allow wild stocks to recover.

251 Develop artificial propagation techniques to provide fish for conducting research (priority 3).

To conduct research on native Delta fish, artificial propagation techniques need to be developed.

252 Mark all hatchery fish with easily recognizable tags or marks (priority 3).

Hatchery fish can be used to take fishing pressure off wild fish. To accomplish this, it is necessary for anglers to be able to easily recognize hatchery fish. Easily recognizable tags or marks (e.g., adipose fin clip) should be placed on hatchery fish for this purpose.

3 Reduce the effects of introduced aquatic species (predation or disease).

Introduced species may be a large cause of the decline of native Delta fish. Reducing the adverse effects of these introduced species is an important element to the recovery of native Delta fish.

31 Regulate ship ballast water discharges to eliminate or reduce introductions of exotic species (priority 2).

Ship ballast water discharges have been a source of some of the most detrimental introduced species, including the Asiatic clam (*Potamocorbula amurensis*). These ship ballast water discharges should be regulated to minimize the introductions of organisms that may compete with or prey upon native Delta fish.

32 Control existing harmful introduced species (priority 3).

Species that have been introduced in the past and have become established in the Delta, tributaries and Suisun Bay currently cause adverse effects on native Delta fish through competition and predation. These species need to be controlled whenever possible. An example of control might be use of freshwater Delta outflows to control expansion of Asiatic clam.

33 Prohibit introductions of new exotic species (priority 2).

Federal, State, and private entities should be banned from introducing additional exotic species into the Delta, tributaries or Suisun Bay. Effects of introductions are difficult to assess, so complete prohibition is necessary.

4 Change and improve enforcement of regulatory mechanisms.

Inadequate regulatory mechanisms and lack of enforcement have had a substantial adverse effect on native Delta fish and have contributed to their decline. Changing regulatory mechanisms to better reflect current understanding of species needs along with improved enforcement of existing mechanisms is anticipated to help reverse the decline of native Delta fish.

41 Set and enforce water quality and flow standards to protect native fish.

The SWRCB has set water quality and flow standards meant to benefit Delta fish species. However, enforcement of these standards has not been uniform. The SWRCB and the USEPA have proposed additional standards that reflect new understanding of the biology and hydrology of the Delta and Suisun Bay.

411 Set water quality standards for the Delta to provide habitat and transport flows, and maintain appropriate salinity and temperature.

The USEPA have proposed water quality standards that attempt to provide habitat and transport flows for Delta fish and provide appropriate salinities and temperatures. Proposed standards are needed to substantially reverse the decline and encourage the recovery of native Delta fish.

4111 Public water projects have responsibility to meet standards (priority 2).

Federal and State agencies that store, license, or control water would share responsibility in meeting standards. The size and scope of these projects are large enough by themselves to substantially reverse the decline of native Delta fish and help in their recovery.

4112 Private water rights holders provide water to implement standards.

The private water rights holders could significantly increase the ability of the public water projects to meet water quality standards. This would speed the reversal of native Delta fish decline and help in their recovery.

41121 Implement water conservation practices that make more water available (priority 2).

Private water rights holders could make more water available through implementation of water conservation practices. This additional water could be used to meet water quality standards.

41122 Time water districts' flood releases to benefit Delta fish (priority 2).

Flood releases in years having high precipitation should be timed to benefit native Delta fish. Coordination with the public water projects would be necessary for maximum benefit to the fish.

42 Designate critical habitat for delta smelt (priority 2).

Designating critical habitat for delta smelt will benefit all native Delta fishes.

43 Improve implementation and enforcement of section 404 of Clean Water Act and section 10 of the Rivers and Harbors Act of 1898.

The Clean Water Act and the River and Harbors Act of 1898 provide protection for native Delta fish. Permit terms and conditions specify actions needed to minimize action effects and provide mitigation for adverse effects. Implementation and enforcement of these Acts will help to recover Delta fish.

431 Set dredging time windows to protect critical life-stages of fish.

Dredging is a source of habitat destruction, mobilization of contaminated sediments, and general disturbance to native Delta fish. Setting seasonal "windows" when dredging can occur that minimize effects on critical life-stages of Delta native fish would help in recovery.

4311 Restrict dredging activity within the Delta to the period between September 1 through November 31 (priority 3).

Critical life-stages of native Delta fish are transported to rearing areas and a "window" will protect these life-stages. Restricting dredging to the period September 1 through November 31 would protect spawning delta smelt, longfin smelt, and Sacramento splittail, and would give some protection to upmigrating and outmigrating salmon.

4312 Restrict dredging activity within Suisun Bay and Marsh to deepwater ship channel maintenance (priority 3).

Critical life-stages of native Delta fish spawn and rear in Suisun Bay and Suisun Marsh. Restricting dredging to deepwater ship channel maintenance in these areas will provide protection to these species.

432 Increase enforcement of U.S. Army Corps of Engineers permits (priority 3).

Current enforcement of permits is limited by inadequate staffing levels and funding. Increased funding targeted at enforcement would remedy this situation.

44 Develop alternative levee maintenance practices (priority 2).

Conventional levee maintenance using rip-rap, as currently practiced by local reclamation boards and U.S. Army Corps of Engineers, eliminates shallow-water and vegetated aquatic habitats. These losses simplify habitat structure, reduce productivity of fish habitat, curtail spawning and rearing habitat, and eliminate escape cover from predators. Alternative levee designs are needed to incorporate natural river berms setback from current levee alignments that allow growth of vegetated shallows along low gradient berm slopes.

5 Conduct monitoring and research to increase understanding of basic biology and management requirements.

Current understanding of the basic Delta native fish biology, ecology, and ecosystem management requirements to promote recovery is limited. Monitoring and research is needed to increase this understanding.

51 Monitor for location and numbers of fish throughout the Delta so that recovery objectives may be implemented and decisions made on success of implementation (priority 2).

Determination of the location and numbers of native Delta fish throughout the Delta during different life-stages is key to understanding their biological needs and what management actions should be implemented to promote recovery.

52 Develop screening criteria for adults, juveniles, and larvae (priority 2).

Screening criteria are currently known for very few fish species. These criteria are usually applicable to only adult and advanced juvenile fish. To benefit other fish species, individual species criteria need to be developed and criteria that screen life-stages should be determined. Most of these criteria are already known for salmon.

53 Conduct toxicological investigations to determine susceptibility of fish to various metals and pesticides (priority 3).

Toxicological investigations need to be conducted both in the field and laboratory to determine susceptibility of native Delta fish to toxic substances.

54 Study effects of introduced species (priority 3).

The effects of introduced species on native Delta fish are only partially understood. Studies should be implemented that increase this understanding and lead to decisions on management actions that decrease effects of introductions.

55 Study green sturgeon life history and ecological requirements (priority 2).

Little information is currently known concerning numbers, distribution, life history, or ecological requirements of green sturgeon. A monitoring program is needed to provide this information so that management actions may be developed that will enable this species to be recovered.

56 Develop or improve models relating numbers of sprng-run, late fall-run, and San Joaquin fall-run spawners to smolt survival rate through the Delta in various water year types (priority 3).

There is a strong stock-recruitment relationship with chinook salmon. However, information currently available relating spawner numbers with smolt survival through the Delta needs improvement. These relationships will vary with water-year type since water temperature and transport flows are dependent on rainfall. Models need to be developed or improved allowing these relationships to be defined.

57 Monitor for Sacramento River late fall-run (priority 3).

Similar to green sturgeon, little is known concerning numbers and distribution of late fall-run. A monitoring program that would provide information on numbers and distribution would enable management actions to be developed that would help recover this fish.

58 Conduct surveys, monitoring, and studies to better understand delta smelt.

Delta smelt are one of the most sensitive fish to habitat loss, diversions, and other adverse conditions within the Delta and Suisun Bay. Surveys, monitoring, and studies that give the geographic location of delta smelt during various times of the year and that show how the fish respond to transport flows, outflows, and location of the 2 ppt isohaline should be done to gain a better understanding factors applicable to a number of native Delta fish.

581 Conduct surveys for adult delta smelt in the San Joaquin River and tributary sloughs from December through April (priority 2).

To determine the presence of spawning adult delta smelt on the San Joaquin River and tributary sloughs, surveys should be done between December 1 and April 30.

582 Monitor the location of the 2 ppt isohaline and relate to Delta 14-day running mean outflow and CDFG surveys that determine delta smelt abundance (priority 2).

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The relationship between Delta 14-day running mean outflow and the 2 ppt isohaline and CDFG surveyed abundance of delta smelt is important in determining transport flows and habitat maintenance flows to rearing habitat in Suisun Bay. A monitoring program should be instituted that allows this relationship to be determined.

59 Investigate fish use of shallow water habitats, flooded vegetation and tidal marshes (priority 2).

510 Investigate feasibility of restoring Delta islands as shallow water habitat (priority 2).

Restoring shallow-water, vegetated habitat would address many of thethreats that constrain recovery potential of native fishes by improving spawning, rearing and migratory habitats, providing slack water and refugial habitat and reducing predation. Shallow-water, vegetated habitat will also reduce entrainment by CVP and SWP by amelioring altered flow patterns.

511 Investigate the feasibility of reintroducing Sacramento perch into the Delta ecosystem (priority 3).

6 Assess effects of Delta native fishes recovery management actions and re-assess prioritization of actions (priority 2).

Effects of the management actions done to recover native Delta fish need to be assessed for effectiveness. This may be done through use of results of surveys, studies, and monitoring described above. When this assessment has been done, management actions should be modified or new ones added as necessary. Subsequently, a reassessment of priorities should be done.

7 Increase public awareness of importance of Delta native fishes.

Public ignorance of the effects of current agricultural practices, urban expansion, commercial exploitation, and habitat alteration has facilitated the decline of native Delta fishes. To successfully reverse this decline and recover these fish, improved public awareness is needed concerning the importance of these fish to the Delta ecosystem. An outreach and public education program should be developed that addresses information gaps and misperceptions concerning Delta native fish and their ecosystem.

71 Assess public attitudes on recovering Delta native fishes (priority 3).

Prior to public education, an assessment of current attitudes toward Delta native fish and their habitat should be conducted. This assessment will allow outreach to be focussed on information gaps and misperceptions. A telephone or form survey should be done that allows the public to indicate knowledge of native Delta fish and feelings toward recovery and habitat improvement. Public meetings to discuss the results of this survey should be scheduled to enable additional input and initiate planning of the outreach effort.

72 Develop a public outreach and education program that increases public awareness of positive effects on healthy fisheries and aquatic habitats (priority 3)..

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Using the results of the public assessment, an outreach program should be developed that increases public awareness of positive effects on recovery of native Delta fishes. A implementation schedule for this outreach program that coincides with recovery actions should be developed to enable maximum cooperation from both public and private sectors. Publics such as party boat operators should be targeted for education in identifying Delta native species susceptible to angling. Pamphlets are needed to aid the public in identifying fishes to the species level. This is especially important for green sturgeon, which is often misidentified as white sturgeon.

C-048496

SPECIES PRINCIPAL OCCURRENCES IN THE BAY

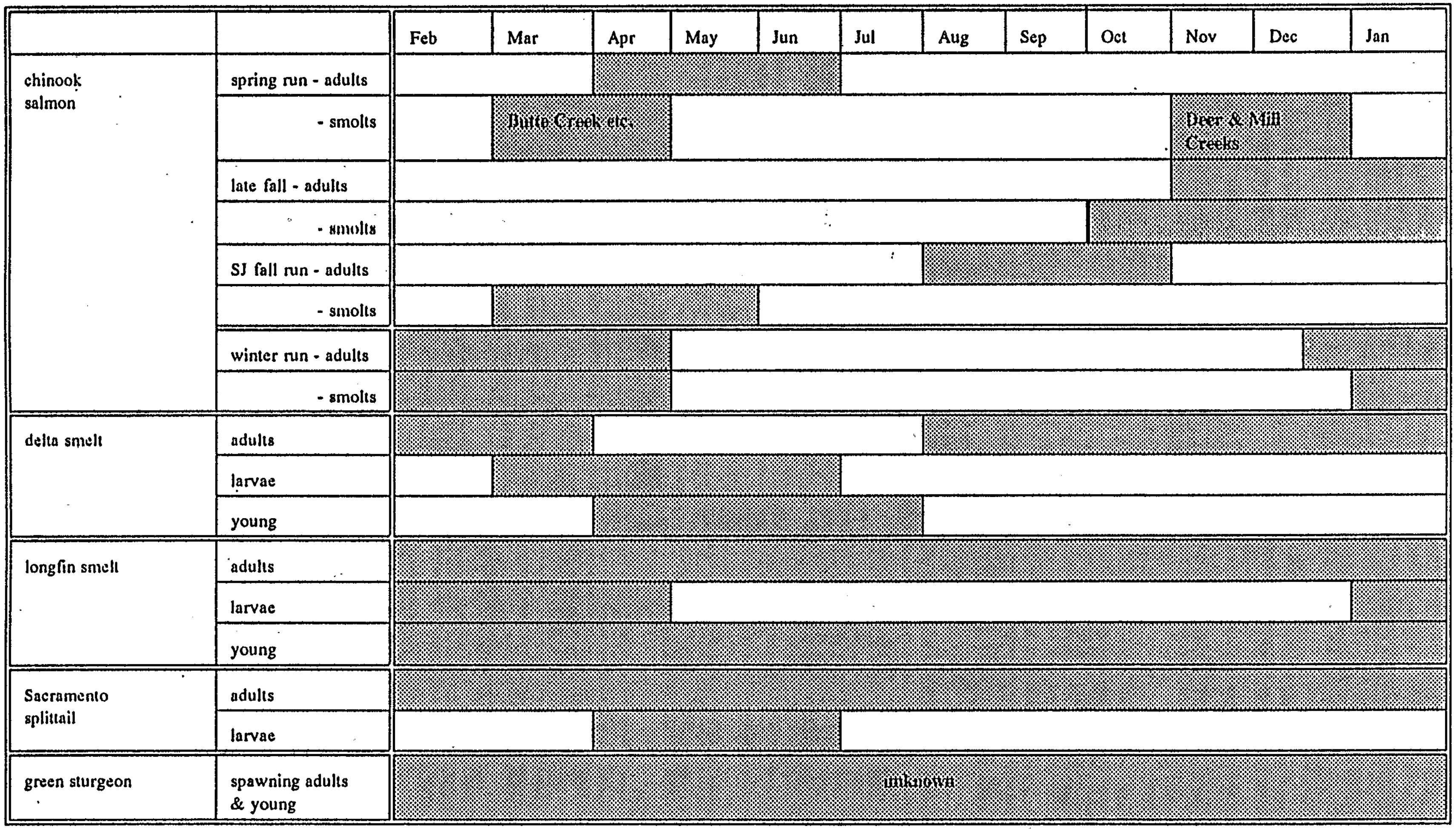

Figure 10.1 Timing of species occurrences in the Delta.

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Recovery Plan Implementation Schedule for Sacramento-San Joaquin Delta

Priority #	Task #	Task Description	Task Duration (Yrs)	Responsible Party	Total Cost*	Cost est.($1,000,000) FY 95	96	97	98	99
Increase freshwater flows										
1	1112	Provide transport inflows-outflows Sacramento River	Ongoing	CVP/ SWP FERC, ACE, Private	30	6	6	6	6	6
1	1113	Provide transport inflows-outflows San Joaquin River	Ongoing	CVP/ SWP FERC, ACE, Private	10	2	2	2	2	2
1	11141	Place 2 ppt at Roe Island	Ongoing	CVP/ SWP FERC, ACE, Private	2.5	0.5	0.5	0.5	0.5	0.5
1	11142	Place 2 ppt at Chipps Island	Ongoing	CVP/ SWP FERC, ACE, Private	0.5	0.1	0.1	0.1	0.1	0.1
1	11143	Place 2 ppt at confluence	Ongoing	CVP/ SWP FERC, ACE, Private	0.5	0.1	0.1	0.1	0.1	0.1
Reduce entrainment losses to water diversions										
1	12111	Provide flows and restrict pumping	Ongoing	CVP/ SWP	10	2	2	2	2	2
1	12112	Provide flows on Sacramento River to protect salmon smolts	Ongoing	CVP/ SWP	1	0.2	0.2	0.2	0.2	0.2
1	12113	Provide flows on San Joaquin River to protect salmon smolts	Ongoing	CVP/ SWP	1	0.2	0.2	0.2	0.2	0.2

* Cost estimates were made without review by an economist and have a high degree of uncertainty (±50 percent)

Recovery Plan Implementation Schedule for Sacramento-San Joaquin Delta

Priority #	Task #	Task Description	Task Duration (Yrs)	Responsible Party	Total Cost*	Cost est.($1,000,000) FY 95	96	97	98	99
Reduce effects of dredging										
1	133	Eliminate loss of shallow-water habitat	Ongoing	CVP/ SWP ACE	0.5	0.1	0.1	0.1	0.1	0.1
Reduce effects of harvest										
1	242	Change regulations	1	DFG	0.1	0.1				
Develop additional shallow-water habitat, riparian vegetation zones, and tidal marsh										
2	1121	Develop Delta habitat and vegetation zones	Ongoing	SWP ACE PG+E	2.5	0.5	0.5	0.5	0.5	0.5
2	1122	Develop Suisun Marsh and Suisun Bay habitat and vegetation zones	Ongoing	SWP ACE PG+E	2.5	0.5	0.5	0.5	0.5	0.5
2	11221	Restore spawning habitat in up-stream freshwater areas	Ongoing	SWP ACE PG+E DFG	2.5	0.5	0.5	0.5	0.5	0.5
2	11222	Restore rearing habitat in tidal areas	Ongoing	SWP ACE PG+E DFG	2.5	0.5	0.5	0.5	0.5	0.5
Reduce entrainment losses to water diversions										
2	1213	Reduce predation at Clifton Court Forebay and other diversions	Ongoing	CVP/ SWP	0.5	0.1	0.1	0.1	0.1	0.1

Recovery Plan Implementation Schedule for Sacramento-San Joaquin Delta

Priority #	Task #	Task Description	Task Duration (Yrs)	Responsible Party	Total Cost*	Cost est.($1,000,000) FY 95	96	97	98	99
2	1214	Screen diversions at Rock Slough	Ongoing	CVP/ CCWD DFG	2	1	1			
2	1217	Evaluate diversion of San Joaquin salmon at Old River	Ongoing	CVP/ SWP DFG	1	0.2	0.2	0.2	0.2	0.2
2	12181	Close Delta cross channel gates with recent time monitoring or a seasonal "window"	Ongoing	CVP DFG	0.5	0.1	0.1	0.1	0.1	0.1
2	12191	Evaluate Georgiana Slough hydroacoustic barrier or deflector	Ongoing	CVP DFG ACE	5	1	1	1	1	1
2	1221	Reduce entrainment at PG+E and other private diverters	Ongoing	PG+E DFG FWS	1	0.2	0.2	0.2	0.2	0.2
Reduce effects of toxic substances from urban non-point sources										
2	1411	Change application practices	5	USEPA USDA	0.5	0.1	0.1	0.1	0.1	0.1
2	1412	Change residence times	5	USEPA USDA	0.5	0.1	0.1	0.1	0.1	0.1
2	1413	Retire agricultural lands	5	FWS	10	2	2	2	2	2

Recovery Plan Implementation Schedule for Sacramento-San Joaquin Delta

Priority #	Task #	Task Description	Task Duration (Yrs)	Responsible Party	Total Cost*	Cost est.($1,000,000) FY 95	96	97	98	99
Reduce effects of contaminants										
2	1414	Control point sources of toxic substances	Ongoing	USEPA/ SWRCB	0.5	0.1	0.1	0.1	0.1	0.1
2	1431	Monitor urban non-point sources	5	USEPA SWRCB	0.5	0.1	0.1	0.1	0.1	0.1
2	1432	Educate public and private sectors	5	FWS USEPA	0.5	0.1	0.1	0.1	0.1	0.1
Reduce effects of harvest										
2	221	Halt green sturgeon sportfishing	5	DFG	0.5	0.1	0.1	0.1	0.1	0.1
2	222	Educate anglers to recognize green sturgeion	5	DFG	0.5	0.1	0.1	0.1	0.1	0.1
2	223	Tag green sturgeon	5	DFG	0.5	0.1	0.1	0.1	0.1	0.1
2	23	Control illegal harvest	5	DFG	0.5	0.1	0.1	0.1	0.1	0.1
2	241	Institute selective fishery	5	DFG	0.5	0.1	0.1	0.1	0.1	0.1
Reduce the effects of introduced species										
2	31	Regulate ship ballast water discharges	1	USCG	0.1	0.1				
2	33	Prohibit exotic species introductions	2	USDA DFG	0.2	0.1	0.1			

Recovery Plan Implementation Schedule for Sacramento-San Joaquin Delta

Priority #	Task #	Task Description	Task Duration (Yrs)	Responsible Party	Total Cost*	Cost est.($1,000,000) FY 95	96	97	98	99
Change and improve enforcement of regulatory mechanisms										
2	411	Set Delta water quality standards	2	USEPA SWRCB	0.2	0.1	0.1			
2	4111	Public water projects implement water quality standards	Ongoing	USEPA SWRCB CVP/ SWP	0.5	0.1	0.1	0.1	0.1	0.1
2	4112	Private water rights holders provide water	Ongoing	SWRCB	1	0.2	0.2	0.2	0.2	0.2
2	41121	Implement water conservation practices	Ongoing	SWRCB	0.5	0.1	0.1	0.1	0.1	0.1
2	41122	Flood releases to benefit Delta fish	Ongoing	SWRCB	0.5	0.1	0.1	0.1	0.1	0.1
2	42	Designate critical habitat for delta smelt	Ongoing	FWS	0					
2	44	Develop alternative levee maintenance	Ongoing	ACE	0.5	0.1	0.1	0.1	0.1	0.1
Conduct monitoring and research										
2	51	Monitor Delta for location and numbers of fish	Ongoing	CVP/ SWP DFG	0.5	0.1	0.1	0.1	0.1	0.1
2	52	Develop fish screening criteria	3	CVP/ SWP DFG	0.3	0.1	0.1	0.1		

Recovery Plan Implementation Schedule for Sacramento-San Joaquin Delta

Priority #	Task #	Task Description	Task Duration (Yrs)	Responsible Party	Total Cost*	Cost est.($1,000,000) FY 95	96	97	98	99
2	581	Survey for delta smelt in San Joaquin River	Ongoing	CVP/ SWP DFG	0.5	0.1	0.1	0.1	0.1	0.1
2	582	Monitor location of 2 ppt isohaline	Ongoing	CVP/ SWP DFG	0.5	0.1	0.1	0.1	0.1	0.1
2	59	Investigate fish use of shallow-water habitat, flooded vegetation, tidal marshes	5	DFG	0.5	0.1	0.1	0.1	0.1	0.1
2	510	Investigate restoring Delta islands as shallow-water habitat	5	DFG	0.5	0.1	0.1	0.1	0.1	0.1
Assess effects of Delta native fishes recovery management actions and re-assess prioritization of actions										
2	6	Assess and reprioritize recovery management actions	1	FWS DFG	0.1	0.1				
Increase freshwater flows										
3	1111	Increase Delta inflows	Ongoing	CVP/ SWP	1	0.2	0.2	0.2	0.2	0.2
Reduce entrainment losses to water diversions										
3	12121	Change facility operations	Ongoing	CVP/ SWP	0.5	0.1	0.1	0.1	0.1	0.1
3	12122	Remove green sturgeon from Clifton Court Forebay	5	SWP DFG	1	0.2	0.2	0.2	0.2	0.2

Recovery Plan Implementation Schedule for Sacramento-San Joaquin Delta

Priority #	Task #	Task Description	Task Duration (Yrs)	Responsible Party	Total Cost*	Cost est.($1,000,000) FY 95	96	97	98	99
3	1215	Restrict CCWD diversions with recent-time monitoring or a seasonal "window"	Ongoing	CVP CCWD DFG	0.5	0.1	0.1	0.1	0.1	0.1
3	12161	Restrict NBA diversions with recent-time monitoring or a seasonal "window"	Ongoing	DWR DFG	0.5	0.1	0.1	0.1	0.1	0.1
Reduce entrainment at agricultural diversions										
3	12221	Screen Delta agricultural diversions	Ongoing	ACE NMFS FWS	5	1	1	1	1	1
3	12222	Consolidate Delta agricultural	5	ACE	1	0.2	0.2	0.2	0.2	0.2
3	12223	Restrict Delta agricultural diversions when fish are present	5	ACE DFG	1	0.2	0.2	0.2	0.2	0.2
Reduce the effects of dredging										
3	1311	Time dredging for minimal tidal movement	Ongoing	ACE DFG	0.5	0.1	0.1	0.1	0.1	0.1
3	1312	Use silt curtains or suction dredges	Ongoing	ACE	1	0.2	0.2	0.2	0.2	0.2

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Priority #	Task #	Task Description	Task Duration (Yrs)	Responsible Party	Total Cost*	Cost est.($1,000,000) FY 95	96	97	98	99
Reduce effects of industrial and municipal dumping of toxic substances in Delta										
3	1421	Separate industrial from municipal sewage	5	USEPA SWRCB	1	0.2	0.2	0.2	0.2	0.2
3	1422	Tertiary treat sewage	5	USEPA SWRCB	1	0.2	0.2	0.2	0.2	0.2
Reduce the effects of harvest										
3	211	Institute selective San Joaquin salmon fishery	5	DFG	2	0.4	0.4	0.4	0.4	0.4
3	212	Change San Joaquin River angling regulations	1	DFG	0.1	0.1				
Improve hatchery management										
3	251	Develop artificial propagation techniques	5	FWS DFG	1	0.2	0.2	0.2	0.2	0.2
3	252	Mark hatchery fish	Ongoing	FWS DFG	1	0.2	0.2	0.2	0.2	0.2
Reduce the effects of introduced species										
3	32	Control existing harmful introduced species	Ongoing	CVP/ SWP DFG	2	0.4	0.4	0.4	0.4	0.4
Set dredging time windows										
3	4311	Restrict dredging in Delta	Ongoing	ACE	0.5	0.1	0.1	0.1	0.1	0.1
3	4312	Restrict dredging in Suisun Bay and Suisun Marsh	Ongoing	ACE	0.5	0.1	0.1	0.1	0.1	0.1

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Priority #	Task #	Task Description	Task Duration (Yrs)	Responsible Party	Total Cost*	Cost est.($1,000,000) FY 95	96	97	98	99
3	432	Increase ACE enforcement	5	ACE FWS	2	0.4	0.4	0.4	0.4	0.4
Conduct monitoring and research										
3	53	Conduct toxicological investigations	5	CVP/ SWP DFG FWS	2	0.4	0.4	0.4	0.4	0.4
3	54	Study introduced species	Ongoing	CVP/ SWP DFG	0.5	0.1	0.1	0.1	0.1	0.1
3	56	Develop or improve salmon models	5	DFG	0.5	0.1	0.1	0.1	0.1	0.1
3	57	Monitor for Sacramento River late fall-run	5	DFG	0.5	0.1	0.1	0.1	0.1	0.1
3	511	Investigate feasibility of reintroducing Sacramento perch into Delta	5	DFG	0.5	0.1	0.1	0.1	0.1	0.1
Increase public awareness of importance of Delta native fishes										
3	71	Assess public attitudes	1	FWS	0.1	0.1				
3	72	Develop and implement outreach and education program	5	FWS	0.5	0.1	0.1	0.1	0.1	0.1

GLOSSARY

ACE - U. S. Army Corps of Engineers

Alevins - Yolk-bearing salmon larvae.

Amphipods - Small crustaceans used by fish for food.

Anadromous - Describes fish that are born in fresh water, migrate to sea, and return to fresh water to spawn. Examples include salmon, sturgeon, shad, and smelt.

Autocorrelation - Interactions among measurements that make relationships between measurements difficult to understand.

Bathymetry - Describes the bottom configuration of bodies of water.

Biomass - Total mass of all members of a given population, community, or other study group. It is a measure of total biological quantity, without regard for details such as age, gender, or species.

BKD - Bacterial Kidney Disease. A serious salmonid disease that can cause death or serious impairment.

BLM - Bureau of Land Management

Branchiostegal rays - Paired structures on either side and below the jaw that protect the gills. Counts of branchiostegal rays are used by taxonomists to identify fish.

CCWD - Contra Costa Water District

CDFG - California Department of Fish and Game

Cladocerans - Small crustaceans used by fish for food.

Cline - A gradual change in physical and genetic characteristics over a geographic transect. For example, the northern cline of longfin smelt have shorter pectoral fins than their southern neighbors.

cfs - cubic feet per second

Copepods - Small crustaceans used by fish for food.

CVP - Central Valley Project

Delisting - The process of removing an endangered or threatened species from the endangered species list.

Demersal - Sinks to the bottom. Refers to a type of fish egg that sinks, rather than floats.

DWR - California Department of Water Resources

Entrainment - Loss of fish into human-made structures.

Euryhaline - A species that tolerates a wide range of salinities.

FERC - Federal Energy Regulatory Commission

FMWT - Fall midwater trawl, conducted by CDFG since 1967.

Fry - The first free-swimming life stage of a salmonid.

Heterocercal - Shark-like tail, with the upper lobe longer than the lower lobe.

Hydrograph - A record of river flow over time.

IHN - Infectious Hematopoietic Necrosis. A serious salmonid disease that can cause death or serious impairment.

Introgressive hybridization - Hybridization that involves exchange of genes into the parental genome, resulting in an alteration of the parental stock.

Isohaline - An artificial line denoting changes in salinity in a body of water.

Mixing zone - The area in an estuary where sea water and fresh water meet. The mixing zone is characterized by high productivity and salinities of around 2 ppt.

mS/cm - MilliSiemens per centimeter, a measure of electrical conductivity (amount of ions) in the water. Often used as a surrogate for salinity.

NMFS - National Marine Fisheries Service

ODFW - Oregon Department of Fish and Wildlife.

Operculae - Bony plates covering fish gills.

Parr - A juvenile salmonid, generally the stage between fry and smolt.

PG and E - Pacific Gas and Electric Company

Phytoplankton - Microscopic algae that form the base of the aquatic food chain.

Planktivores - Fish that eat plankton, either zoo- (animal) or phyto- (plant) plankton.

Piscivore - Fish that eat other fish.

ppm - parts per million

ppt - parts per thousand

RBDD - Red Bluff Diversion Dam

Redd - A spawning nest made in the gravel bed of a river by salmon or steelhead.

Rotifers - Microscopic crustaceans used by fish for food.

SBI - Striped Bass Index, developed by CDFG to track changes in the striped bass population in the Delta.

Smolt - The life stage of a salmon in which physiological changes prepare the fish for transition from freshwater to marine life. Usually marks the onset of active downstream migration.

SL - Standard length, measured from tip of the snout to hypural bone (approximately origin of caudal fin).

Swimbladder - A gas-filled organ that allows fish to maintain neutral buoyancy.

SWP - State Water Project

SWRCB - State Water Resources Control Board

TL - Total length, measured from tip of the snout to end of the tail.

USBR - U. S. Bureau of Reclamation

USCG - U. S. Coast Guard

UCD - University of California, Davis.

USDA - U. S. Department of Agriculture

USEPA - United States Environmental Protection Agency

USFWS - U. S. Fish and Wildlife Service

USGS - U. S. Geological Survey

X2 - The point in the estuary where the 2 ppt isohaline is located.